UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION IV
611 RYAN PLAZA DRIVE, SUITE 400
ARLINGTON, TEXAS 76011-8064

March 21, 2002

EA-02-046

Garry L. Randolph, Senior Vice
President and Chief Nuclear Officer
Union Electric Company
P.O. Box 620
Fulton, Missouri 65251

SUBJECT: NRC AUGMENTED INSPECTION TEAM (AIT) REPORT 50-483/02-07 AND PRELIMINARY WHITE FINDING - CALLAWAY PLANT

Dear Mr. Randolph:

On February 27, 2002, the NRC completed an Augmented Inspection at your Callaway Plant. The enclosed report documents the inspection findings which were discussed on February 27, 2002, with you and other members of your staff.

This inspection examined activities conducted under your license as they relate to safety and compliance with the Commission's rules and regulations and with the conditions of your license. Within these areas, the inspection consisted of selected examination of procedures and representative records, observations of activities, and interviews with personnel.

The report discusses an issue that appears to have low to moderate safety significance. The issue involved the failure, on multiple occasions, to identify and correct a risk significant condition adverse to quality regarding the degraded condition of the condensate storage tank diaphragm seal. Foam from the degraded seal was eventually entrained in the auxiliary feedwater system suction piping and caused an on-demand failure of an auxiliary feedwater pump, while plant operators reduced reactor power on December 3, 2001. The finding was assessed using the Significance Determination Process (SDP) and was preliminarily determined to be White. The finding has a low to moderate safety significance under the SDP because it involved an increase in the core damage frequency of between 1E-6/year and 1E-5/year.

The failure to promptly identify and correct the degraded diaphragm seal is also an apparent violation of Criterion XVI of Appendix B to 10 CFR Part 50 and is being considered for escalated enforcement action in accordance with the "General Statement of Policy and Procedure for NRC Enforcement Actions" (Enforcement Policy), NUREG-1600. The current Enforcement Policy is included on the NRC's website at http://www.nrc.gov/what-we-do/regulatory/enforcement.html.

Before the NRC makes a final decision on this matter, we are providing you an opportunity to request a Regulatory Conference where you would be able to provide your perspectives on the significance of the finding, the basis for your position, and whether you agree with the apparent violation. If you choose to request a Regulatory Conference, we encourage you to submit your evaluation and any differences with the NRC evaluation at least one week prior to the conference in an effort to make the conference more efficient and effective. If a conference is held, it will be open for public observation. The NRC will also issue a press release to announce the conference.

Please contact Dr. Dale A. Powers at (817) 860-8195 within 10 days of the date of this letter to notify the NRC of your intentions. If we have not heard from you within 10 days, we will continue with our significance determination and enforcement decision and you will be advised by separate correspondence of the results of our deliberations on this matter.

Since the NRC has not made a final determination in this matter, no Notice of Violation is being issued for the corrective action program finding at this time. In addition, please be advised that the number and characterization of the apparent violations described in the enclosed report may change as a result of further NRC review.

The NRC inspection also identified one additional issue that was evaluated under the risk significance determination process as having very low safety significance (Green). The NRC has also determined that a violation was associated with this issue. The violation is being treated as a noncited violation (NCV), consistent with Section VI.A of the Enforcement Policy. The NCV is described in the subject inspection report. If you contest the violation or significance of the NCV, you should provide a response within 30 days of the date of this inspection report, with the basis for your denial, to the U.S. Nuclear Regulatory Commission, ATTN: Document Control Desk, Washington, DC 20555-0001, with copies to the Regional Administrator, U.S. Nuclear Regulatory Commission, Region IV, 611 Ryan Plaza Drive, Suite 400, Arlington, Texas 76011; the Director, Office of Enforcement, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001; and the NRC Resident Inspector at the Callaway Plant facility.

In accordance with 10 CFR 2.790 of the NRC's "Rules of Practice," a copy of this letter, its enclosure, and your response will be made available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of NRC’s document system (ADAMS). ADAMS is accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html (the Public Electronic Reading Room).

Should you have any questions concerning this inspection, we will be pleased to discuss them with you.

Sincerely,

/RA/

Arthur T. Howell III, Director
Division of Reactor Safety

Docket: 50-483
License: NPF-30

Enclosure:
NRC Inspection Report
50-483/02-07

cc w/enclosure:
Professional Nuclear Consulting, Inc.
19041 Raines Drive
Derwood, Maryland 20855

John O'Neill, Esq.
Shaw, Pittman, Potts & Trowbridge
2300 N. Street, N.W.
Washington, D.C. 20037

Mark A. Reidmeyer, Regional
Regulatory Affairs Supervisor
Regulatory Affairs
AmerenUE
P.O. Box 620
Fulton, Missouri 65251

Manager - Electric Department
Missouri Public Service Commission
301 W. High
P.O. Box 360
Jefferson City, Missouri 65102

Ronald A. Kucera, Deputy Director
for Public Policy
Department of Natural Resources
205 Jefferson Street
Jefferson City, Missouri 65101

Otto L. Maynard, President and
Chief Executive Officer
Wolf Creek Nuclear Operating Corporation
P.O. Box 411
Burlington, Kansas 66839

Dan I. Bolef, President
Kay Drey, Representative
Board of Directors Coalition
for the Environment
6267 Delmar Boulevard
University City, Missouri 63130

Lee Fritz, Presiding Commissioner
Callaway County Courthouse
10 East Fifth Street
Fulton, Missouri 65251

J. V. Laux, Manager
Quality Assurance
AmerenUE
P.O. Box 620
Fulton, Missouri 65251

Jerry Uhlmann, Director
State Emergency Management Agency
P.O. Box 116
Jefferson City, Missouri 65101

Gary McNutt, Director
Section for Environmental Public Health
P.O. Box 570
Jefferson City, Missouri 65102-0570

John D. Blosser, Manager
Regulatory Affairs
AmerenUE
P.O. Box 620
Fulton, Missouri 65251

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ENCLOSURE 1

U.S. NUCLEAR REGULATORY COMMISSION
REGION IV

Docket:	50-483
License:	NPF-30
Report No.:	50-483/02-07
Licensee:	Union Electric Company
Facility:	Callaway Plant
Location:	Junction Highway CC and Highway O Fulton, Missouri
Dates:	January 28 through February 27, 2002
Inspectors:	Troy W. Pruett, Senior Reactor Analyst (Team Leader) Timothy L. Hoeg, Senior Resident Inspector Terry W. Jackson, Resident Inspector Jack N. Donohew, Project Manager
Approved By:	Arthur T. Howell III
Attachments:	Supplemental Information Augmented Inspection Team Charter Sequence of Events System Figures

SUMMARY OF FINDINGS

Callaway Plant
NRC Inspection Report 50-483/02-07

IR 05000483-02-07; on 01/28-02/27/2002; Union Electric Co; Callaway Plant. Augmented Inspection Report; Problem Identification and Resolution, Modifications. One preliminary White finding.

The inspection was conducted by regional inspectors and an Office of Nuclear Reactor Regulation project manager. The inspection identified one apparent violation and one noncited violation of NRC requirements. The significance of most findings is indicated by their color (Green, White, Yellow, Red) using Inspection Manual Chapter 0609 "Significance Determination Process." Findings for which the significance determination process does not apply are indicated by "No Color" or by the severity level of the applicable violation. The NRC's program for overseeing the safe operation of commercial nuclear power reactors is described at its Reactor Oversight Process website at http://www.nrc.gov/NRR/OVERSIGHT/ASSESS/index.html.

Identification and Resolution of Problems

The team determined that several opportunities were missed to promptly identify and correct a risk significant condition adverse to quality involving the degraded condition of the condensate storage tank diaphragm seal. Quality assurance personnel were not actively involved in providing oversight of the event review team and root cause investigation processes. The event review team process did not ensure that statements were obtained from all personnel involved in the event. The corrective action program did not include guidance or expectations on the assignment of appropriate resources to review the highest classification of significant conditions adverse to quality. Minimal resources were initially assigned to the root cause investigation and may have contributed to the delay in identifying the degraded diaphragm seal. Based on interviews with the licensee's staff and a review of the corrective action program procedure, the team determined that licensed operators were only notified of equipment deficiencies if the individual discovering the condition believed there was an immediate impact on nuclear, plant, or personnel safety. Consequently, the potential existed for operability decisions to be made by non-licensed personnel. The operability evaluation program did not implement the guidance provided in NRC Generic Letter 91-18, "Information to Licensees Regarding NRC Inspection Manual Section on Resolution of Degraded and Nonconforming Conditions."

Cornerstone: Mitigating Systems

- TBD. Between January 1992 and January 31, 2002, several opportunities were missed to promptly identify and correct a significant condition adverse to quality involving foreign material in the auxiliary feedwater system and condensate storage tank. The failure to promptly identify the degraded condition resulted in the failure of an auxiliary feedwater pump on December 3, 2001. In addition, between January 25 and 29, 2002, the identification of a significant condition adverse to quality involving the as-found condition of the degraded diaphragm seal was not reported to the appropriate levels of management. The multiple examples of missed opportunities to identify a significant condition adverse to quality was a violation of 10 CFR Part 50, Appendix B, Criterion XVI and also represented a significant human performance cross cutting issue involving the timely recognition of degraded conditions.

The finding had greater than minor significance because there was a credible impact on plant safety. Specifically, auxiliary feedwater Pump A failed to run when started by operations personnel during a plant shutdown. Had a plant event occurred, the potential existed for foam from the degraded condensate storage tank diaphragm to fail one or more auxiliary feedwater pumps. The failure of an auxiliary feedwater pump would have adversely affected the decay heat removal critical safety function. A Significance Determination Process Phase 3 analysis preliminarily determined that the issue had low to moderate safety significance (White). This finding was entered in the licensee's corrective action program as Callaway Action Request System Item CARS 200107423.

- Green. Calculations for auxiliary feedwater pump net positive suction head did not account for nitrogen saturated water. The failure of calculational methods to verify the adequacy of net positive suction head requirements for the auxiliary feedwater pumps was a violation of 10 CFR Part 50, Appendix B, Criterion III.

  The failure to account for nitrogen saturated water in the net positive suction head calculation for the AFW pumps was more than minor because there was a credible impact on safety in that the available margin of net positive suction head was reduced by 11 feet. Using Phase 1 of the Significance Determination Process, the issue was determined to be of very low safety significance because adequate available net positive suction head remained after accounting for dissolved nitrogen. Therefore, the auxiliary feedwater pump would have remained available during an actual plant event. The finding was entered in the licensee's corrective action program as Callaway Action Report System Item CARS 200200485.

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Report Details

1.0 Description of Event and Chronology

1.1 System Descriptions

Auxiliary Feedwater System

The auxiliary feedwater (AFW) system has 2 motor-driven pumps (A and B) and 1 turbine-driven pump. The pumps were normally aligned through a common suction line to the non-safety related condensate storage tank (CST). The essential service water system was credited as the safety-related source of make-up water to the steam generators. The AFW pump suction automatically switched from the CST to the essential service water system following a low level condition in the CST (See Figure 1).

Condensate Storage Tank Diaphragm

The CST diaphragm was a rigid structure that floated on the surface of the water to minimize the oxygen content of the water in the CST. The diaphragm was approximately 43 feet in diameter and constructed of rigid closed cell foam laminated with fiberglass and polyester resin. A seal was attached to the diaphragm and located between the outer periphery and the inner surface of the CST. The seal was constructed of soft pliable polyurethane foam covered with a Teflon-coated fiberglass fabric. The fabric reduced the frictional forces between the seal and the inside wall of the CST when the water level fluctuated (See Figure 2).

1.2 Event Summary

On December 3, 2001, at 1:15 p.m., operations personnel commenced a reactor shutdown to repair a leaking main generator bushing. At 10:39 p.m, the Number 4 main turbine bearing high vibration alarm annunciated in the main control room. At 10:48 p.m., the Number 4 bearing vibration increased to 10 mils and operations personnel manually tripped the main turbine. Operations personnel prepared to reduce main condenser vacuum to alleviate the increasing Number 4 bearing vibration. In anticipation of breaking main condenser vacuum, operations personnel started AFW Pump B followed by AFW Pump A. At 10:57 p.m., the Number 4 bearing vibration exceeded 15 mils and operations personnel broke main condenser vacuum. At 10:58 p.m., operations personnel observed reduced pressure and flow from AFW Pump A and no flow to Steam Generators B and C. Operations personnel started the turbine-driven AFW pump and dispatched the field supervisor and an equipment operator to AFW Pump Room A. The field supervisor and the equipment operator observed that AFW Pump A had no leak-off flow from the outboard pump packing. The field supervisor left AFW Pump Room A to inspect the turbine-driven AFW pump. Upon returning to AFW Pump Room A, the field supervisor and the equipment operator observed that the AFW Pump A outboard pump packing housing was hot to the touch. The field supervisor contacted the main control room and recommended that AFW Pump A be secured. At 11:07 p.m., main control room personnel secured AFW Pump A. Operations personnel continued to cool down the reactor coolant system and entered Mode 3 at 11:19 p.m.

1.3 Preliminary Risk Significance of Event

Following the December 3, 2002, failure of AFW Pump A, the NRC completed an evaluation of the preliminary risk significance. The analysis determined that the conditional core damage probability (CCDP) was approximately 1.1E-6. The CCDP is the probability of core damage over a period of time given a specific plant condition. The CCDP analysis assumed that there was no potential for common cause failure of the remaining two AFW pumps and that the duration associated with the failure of AFW Pump A was less than 30 days. In response to the failure of AFW Pump A, the NRC determined that a Special Inspection Team (SIT) would assess the causes of the event during the week of January 28, 2002.

On January 27, 2002, the licensee's root cause investigation determined that polyurethane foam from a degraded CST floating diaphragm may have caused the failure of AFW Pump A.

On January 28, 2002, the SIT determined that the duration of the degraded condition could have been greater than 1 year. In addition, the SIT determined that the potential existed for common cause failure of the AFW system or multiple AFW pumps. The NRC completed an additional analysis of the event and determined that the new estimated CCDP was in the range of approximately 5E-5 to 5E-4.

NRC Management Directive 8.3, "NRC Incident Investigation Program," required the consideration of the initiation of an Augmented Inspection Team (AIT) when the estimated CCDP was greater than or equal to 1E-5. Based on the potential for a substantial increase in risk stemming from common mode failure implications, the NRC upgraded the SIT to an AIT on January 31, 2002.

1.4 Sequence of Events

The team developed a detailed sequence of events and organizational response time-line. The time-line included applicable events and actions before, during, and following the failure of AFW Pump A on December 3, 2001. The time-line was generated from control room computer printouts, operator logs, written records, and interviews with members of the licensee's staff. The team's review satisfied the activities associated with AIT Charter Element 1, "Develop a complete description and sequence of events related to the subject AFW pump failure (including the degraded CST floating diaphragm), and operator actions taken in response to regain feedwater flow." The AIT Charter is provided as Attachment 2. The detailed sequence of events is provided as Attachment 3.

2.0 Human Factors and Procedural Aspects of the Event

a. Inspection Scope

The team reviewed operator actions associated with the failure of AFW Pump A and the actions taken to restore feedwater flow to Steam Generators B and C. The team interviewed operations personnel, evaluated control room logs and trend data, analyzed

AFW pump performance data, and reviewed control room operating procedures. The team's review satisfied a portion of the activities associated with AIT Charter Element 5, "Identify any human factor, procedural or quality assurance deficiencies that may have contributed to the condition."

b. Observations and Findings

No deficiencies were identified with the operator actions associated with the event or with procedures utilized during the event.

3.0 Root Cause of Equipment Failures

3.1 Auxiliary Feedwater Pump A Root Cause

a. Inspection Scope

The team reviewed the results of the licensee's investigation documented in Callaway Action Request System Item CARS 200107423, "Auxiliary Feedwater System Event Review," to determine if the root cause was of appropriate scope including; independence, completeness, and accuracy to identify the probable causes of the failure of AFW Pump A. The team reviewed operations documents, corrective action documents, maintenance records, and operating experience. The team completed a walk down of portions of the AFW system and CST. The team also interviewed several members of the licensee's staff. The team's review satisfied a portion of the activities associated with AIT Charter Element 2, "Review the licensee's root and probable cause determination for independence, completeness, and accuracy, including the licensee's assessment of the risk associated with the condition."

b. Observations and Findings

The team determined that the licensee's investigation into the failure of AFW Pump A was of adequate scope and detail to conclude that the pump failure was due to the entrainment of a piece of foam from the CST diaphragm seal. The foam material entered the eye of the first stage impeller and produced a localized low pressure region. The low pressure region caused gas to come out of solution and create voids in AFW Pump A. The voiding led to a partially air-bound pump which was incapable of developing the required pump discharge pressure and flow.

3.2 Corrective Actions Associated With Auxiliary Feedwater Pump A

a. Inspection Scope

The team assessed the licensee's prompt and long-term corrective actions to address the root and probable causes of the failure of AFW Pump A. The team reviewed the licensee's root cause analysis, the event review team report, the past operating and maintenance history for AFW Pump A, surveillance test data, the results of system walkdown inspections, vendor information, boroscopic inspections of the AFW system, and inspections of the CST. The team assessed the adequacy of AFW system inspections by direct observation or by viewing video footage and photographs. The team's review satisfied a portion of the activities associated with AIT Charter Element 7, "Identify and assess the licensee's prompt and long-term corrective actions to address the root and probable causes of the condition."

b. Observations and Findings

The team identified several examples of an apparent violation of 10 CFR Part 50, Appendix B, Criterion XVI, "Corrective Actions." Each of the examples involved a missed opportunity to promptly identify and correct a significant condition adverse to quality associated with foreign material in the AFW system and CST.

On December 3, 2001, operations personnel completed a vent-and-fill of AFW Pump A. Air was vented from the pump casing for approximately 15 seconds. No steam was released during the venting. Therefore, the team determined that the licensee appropriately concluded that the failure of AFW Pump A was not due to steam binding.

On December 4, 2001, the licensee completed a walkdown of AFW Train A. The team reviewed Procedure OSP-AL-00001, "AFW Flow Paths Valve Alignment," Revision 5, which described the proper system alignment for the AFW system. The team also interviewed operations and engineering personnel involved with the system walkdown. The team determined that the licensee appropriately concluded that there was no evidence of an improper valve alignment or an obvious pathway for air-entrainment into the AFW system.

On December 4, 2001, the licensee convened an event review team to gather information that would aid in identifying the root cause of the failure of AFW Pump A. The team reviewed UOTH 01-0047, "Event Review Meeting Minutes: High Main Turbine Vibration, AFAS, and No Flow on A-AFW Pump," and concluded that the report accurately reflected the sequence of events. However, during interviews with operations personnel, the team determined that the event review team did not obtain statements from the two reactor operator trainees who were in the control room at the time of the event, or the equipment operator who was the first person to monitor and vent AFW Pump A. Furthermore, the event review team meeting minutes were not distributed to the control room supervisor, the reactor operator trainees, or the equipment operator for verification of information.

The team assessed the licensee's review of the operational and maintenance history for AFW Pump A. The team also reviewed the previous 2 years of test data collected with Procedure OSP-AL-P001A, "Motor Driven Aux. Feedwater Pump 'A' In Service Test," and the previous 2 years of maintenance activities competed on AFW Pump A. The team determined that the licensee appropriately concluded that past operational and maintenance activities associated with AFW Pump A did not contribute to the root cause.

On December 4, 2001, the licensee initiated Callaway Action Request System Item CARS 200107423, "Auxiliary Feedwater System Event Review," to investigate the event. The licensee classified the significance of Callaway Corrective Action System Item CARS 200107423 as Level 1 and specified that a formal root cause evaluation should be completed. The acting mechanical system engineering supervisor and a root cause analyst from the corrective action group were assigned to complete the investigation. Based on discussions with the licensee's staff, the team determined, on the basis of interviews, that the root cause analyst was not actively involved in the investigation until mid-to-late January 2002. Based on interviews with the licensee's staff and a review of Procedure APA-ZZ-00500, "Corrective Action Program," the team determined that there were no formal requirements or expectations on the formulation of teams to review the highest classification of significant conditions adverse to quality.

On December 5, 2001, the licensee started AFW Pump A in order to troubleshoot and attempt to recreate the failure mechanism. The licensee determined that AFW Pump A could not meet the minimum flow requirements of the surveillance test procedure and that the outboard shaft seal stuffing box temperature increased abnormally. The licensee replaced the outboard shaft seal packing, re-baselined the pump performance criteria, and satisfactorily completed the pump surveillance test. In addition, the licensee implemented compensatory measures to perform shiftly vents of all AFW pumps and decreased the surveillance test interval from quarterly to monthly for each AFW pump (In January 2002, the licensee decreased the AFW Pump A frequency to weekly). The licensee determined that the most probable cause of the AFW Pump A failure was air intrusion into the AFW system. Although no cause had been confirmed, the licensee determined that the compensatory measures involving shiftly pump venting and increased testing were sufficient to declare AFW Pump A operable.

Technical Manual M-021000061, "Instruction Manual for Ingersoll Rand Centrifugal Pumps," Revision 25, recommended opening and inspecting the pump when insufficient pump capacity and stuffing box overheating were experienced. The technical manual troubleshooting chart identified foreign material as a probable cause for both the insufficient flow and stuffing box overheating, which were symptoms experienced on December 3 and 5, 2001. In addition, the guidance in Table 5-2 of Electric Power Research Institute TR-114612-V2, "Pump Troubleshooting," was consistent with the technical manual information. Nevertheless, as of December 5, 2001, the licensee did not consider foreign material as a credible failure mechanism. The team determined that the licensee's lack of an evaluation of foreign material in the AFW system or CST as a possible cause immediately following the event was an example of not promptly identifying and correcting a significant condition adverse to quality. This missed opportunity to promptly identify a condition adverse to quality represented an example of a significant human performance crosscutting issue involving the timely recognition of degraded conditions. The significance of this cross cutting issue and other examples of the apparent violation of 10 CFR Part 50, Appendix B, Criterion XVI, is documented in Section 7.

On December 6, 2001, the licensee formally initiated the investigation into the failure of AFW Pump A. In addition, the licensee added a system engineer to the root cause investigation. A vibrations engineer and a licensed operator were utilized on an as-needed basis.

On December 14, 2001, the licensee contacted the pump vendor and discussed possible causes of the failure of AFW Pump A. The pump vendor recommended that the licensee inspect the seal water piping for a possible flow obstruction. Based on interviews with engineering personnel, the team determined that the licensee continued to believe that foreign material was an unlikely cause since the CST was assumed to be free of foreign material and because the AFW pumps had been operated successfully. Consequently, the licensee determined that the inspection of the seal water line could be delayed until the next regularly scheduled maintenance interval for AFW Pump A. The team determined that not promptly following the vendor's recommendation to inspect the seal water line for obstructions was an additional example of the significant human performance cross cutting issue involving the timely recognition of degraded conditions.

During the January 8, 2002, management meeting, the licensee added individuals from regulatory affairs and engineering to the root cause investigation. In addition, the licensee decided to bring the pump vendor and a pump contractor to the site during the January 14, 2002, maintenance week for AFW Pump A.

Following the January 8, 2002, management meeting, the licensee narrowed the root cause of the failure of AFW Pump A to three possibilities: (1) low net positive suction head (NPSH), (2) nitrogen gas disassociation, or (3) foreign material. However, the licensee continued to believe that foreign material was an unlikely cause since there was no recent activity which would have introduced foreign material into the CST or the AFW system. Therefore, foreign material continued to receive a low priority in the root cause investigation. The team concluded that narrowing the potential root causes to those listed above was appropriate. However, this conclusion could have been reached in a more timely manner and causes not related to the event could have been eliminated sooner. Specifically, the following information was available to the licensee following the event:

1. Evidence of air during the vent-and-fill process for AFW Pump A suggested that either air/gas was entrained into the pump, that gas came out of solution, or that foreign material caused the gas to come out of solution at the eye of the impeller.

2. System walkdowns performed after the event did not identify any source of air intrusion.

3. The inability to re-create a failure of AFW Pump A due to air entrainment in subsequent pump runs on December 5, 2001, demonstrated that air-entrainment was an unlikely cause of pump failure.

4. The absence of air during shiftly venting indicated that air intrusion was unlikely.

5. Vendor and industry information suggested that foreign material was a possible cause for the failure of AFW Pump A.

The team determined that the 35-day delay in identifying the potential root causes was an additional example of the significant human performance cross cutting issue involving the timely recognition of degraded conditions.

10 CFR Part 50, Appendix B, Criterion XVI, requires, in part, that measures be established to assure that conditions adverse to quality, are promptly identified and

corrected. For significant conditions adverse to quality, the measures shall assure that the causes of the condition are determined and corrective actions taken to preclude recurrence. The identification of significant conditions adverse to quality shall be documented and reported to appropriate levels of management.

During the week of January 15, 2002, the licensee contracted the services of the pump vendor, Flowserve, and a pump consultant, Dominion Engineering. The consultants were present during the testing of AFW Pump A on January 15, 2002. The licensee also inspected the seal water cooling line on AFW Pump A and found a piece of foam lodged in the orifice. Even though foreign material was identified in the AFW system, the licensee continued to believe that foreign material was not a credible cause for the failure of AFW Pump A. The team determined that the failure to promptly identify and correct the degraded CST diaphragm seal after discovering foreign material in the seal water cooling line was an example of an apparent violation of 10 CFR Part 50, Appendix B, Criterion XVI (APV 05000483/0207-01). In addition, this missed opportunity to promptly identify a condition adverse to quality represented an additional example of a significant human performance cross cutting issue involving the timely recognition of degraded conditions.

On January 17, 2002, the licensee began ultrasonic testing of the AFW pump suction piping to determine if nitrogen gas was coming out of solution and collecting in the system. The team reviewed Procedure QPC-ZZ-05046, “Ultrasonic Examination Procedure for Determining Liquid Level in Pipes and Components,” Revision 0, and recorded test data obtained between January 17 and 31, 2002. The team determined that the ultrasonic procedure was adequate, and that the licensee’s interpretation of the data was appropriate. The team noted that the licensee believed that air intrusion was the most probable cause of the AFW Pump A failure between December 4, 2001, and January 24, 2002. Therefore, the team concluded that the initiation of ultrasonic testing was untimely in that testing could have commenced at an earlier date to help eliminate air or gas accumulation in the suction piping as a root cause.

On January 23, 2002, with the assistance of the consultants, the licensee eliminated low NPSH and air intrusion as potential root causes of the failure of AFW Pump A. The pump vendor provided a report titled, “Evaluation of Auxiliary Feedwater Pump 1A Event 12/3/01,” and the pump consultant provided a report titled, “Auxiliary Feed Pump Event.”

On January 24, 2002, the licensee increased the level of effort associated with the root cause investigation as preparations were made to inspect the CST for foreign material. The licensee also decided to complete the AFW system inspections during the regularly scheduled maintenance window for each train.

On January 26, 2002, the licensee identified foreign material in the CST (See Sections 3.3 and 3.4).

On January 30, 2002, the licensee initiated boroscopic inspections of AFW Pump B, the turbine-driven AFW pump, AFW system suction piping, and portions of the AFW system discharge piping. The team reviewed several work orders and found that the scope of the inspection activities was appropriate. The following is a sample of work orders reviewed:

- W220254, “Replace Rotating Element on ‘A’ MDAFP”
- W682227, “Suction Piping Inspection”
- W687231, “A MDAFP Discharge Piping Inspection”
- W687232, “B MDAFP Discharge Piping Inspection”
- W687233, “TDAFP Discharge Piping Inspection”

On January 31, 2002, the licensee significantly increased the team size and scope of the root cause investigation.

The team observed portions of the boroscopic inspections and found them to be appropriate. The licensee identified one additional piece of foam lodged in the AFW Pump A casing vent line. No other foreign material was identified. The team determined that the scope of the licensee’s inspections of the AFW system and CST were sufficient to ensure the AFW system would perform its safety function.

3.3 Condensate Storage Tank Diaphragm Root Cause

a. Inspection Scope

The team reviewed the licensee’s root cause investigation documented in Callaway Corrective Action System Item CARS 200107423, to determine if it was of appropriate scope including; independence, completeness, and accuracy to identify the probable causes of the failure of the CST diaphragm. The team reviewed operations documents, corrective action documents, maintenance records, and operating experience associated with the AFW pumps and CST. The team completed a walk down of portions of the AFW system and CST. The team also interviewed several members of the licensee’s staff. The team’s review satisfied a portion of the activities associated with the AIT Charter Element 2, “Review the licensee’s root and probable cause determination for independence, completeness, and accuracy, including the licensee’s assessment of the risk associated with the condition.”

b. Observations and Findings

On January 26 and 27, 2002, the licensee found foreign material in the CST. The foreign material mainly consisted of pieces from the diaphragm seal assembly. The seal materials consisted of a Teflon-coated fiberglass fabric, flexible polyurethane foam, caulking material, and a piece of fiberglass (See Figure 2).

The team determined that the licensee’s investigation of the CST diaphragm seal failure was of adequate scope and detail to conclude that the degraded Teflon-coated fabric and inner foam material was due to constant nitrogen sparging of the CST at 5 standard cubic feet per minute. The nitrogen bubbles from the sparging impinged on the diaphragm seal and increased the wear on a 6-foot section of the approximately 130-foot circumference. The licensee calculated that the impact forces were on the magnitude of 0.02-lb force on each square inch of the lower surface of the seal at a rate of approximately 68,700 cycles per impact site over a 4.5-year period. Once the Teflon coating failed, the same mechanism acted directly on the foam. This failure mechanism continued to occur until sections of foam became detached and settled on the bottom of the tank.

3.4 Corrective Actions Associated With Condensate Storage Tank Degraded Seal

a. Inspection Scope

The team assessed the licensee's prompt and long-term corrective actions to address the root and probable causes of the failure of the CST diaphragm seal. The team reviewed the licensee's root cause analysis, the past operating and maintenance history for the seal, and inspections of the CST. The team assessed the adequacy of CST inspections by direct observation or by viewing video footage and photographs. The team's review satisfied a portion of the activities associated with AIT Charter Element 7, "Identify and assess the licensee's prompt and long-term corrective actions to address the root and probable causes of the condition."

b. Observations and Findings

The team identified an additional example of the apparent violation of 10 CFR Part 50, Appendix B, Criterion XVI. Specifically, members of the licensee's staff failed to notify management of a significant condition adverse to quality.

On January 24, 2002, the licensee initiated efforts to inspect the CST. Initially, the assessment consisted of using a diver to inspect the CST and diaphragm seal. During the diver's inspection, approximately 71 inches of the diaphragm seal was found degraded (See Figure 3). The diver removed a 25-inch section of foam hanging from the diaphragm. The diver also found various pieces of foam, Teflon-coated fabric, caulking, and two rubber pads in the CST sump. The foam found in the CST sump included a section measuring 12 x 3 x 8 inches, a section measuring 2 x 3 x 8 inches, and approximately 10 smaller pieces of foam under 1 cubic inch in total volume. No foam was located outside the sump; however, some caulking and two additional rubber pads were recovered from the CST floor.

The team reviewed Work Orders W202393, "CST Seal Inspection," and W686916, "Camera and Diver Inspection of CST." The diver was given instructions to enter the CST and assess the integrity of the diaphragm seal cover and the attachment of the seal to the diaphragm. In the process of communicating the integrity of the diaphragm seal cover, the licensee's staff incorrectly understood that the seal cover had a single tear at the damaged area and did not have any missing pieces. The fabric found in the CST sump was incorrectly assumed to have been left in the CST during construction of the floating diaphragm. This misunderstanding led senior licensee management to believe the diaphragm seal would not present any impact on plant safety once the repairs outlined in Work Order W686916 were performed.

On January 30, 2002, following a viewing of video footage with the team, senior licensee management contacted the diver and questioned the as-found condition of the seal. Senior licensee management was informed that the Teflon fabric did not have a single tear, but was missing pieces and had jagged edges.

Even though foam was found in the AFW Pump A seal water line, as well as the CST, the licensee's operability evaluation included in Callaway Corrective Action System Item CARS 200200489, "Complete an 'Operability Evaluation' on the CST Due to the

Existence of the Foam Pieces," did not document activities to determine the potential for foreign material to have been retained in other sections of the AFW system. The team interviewed senior licensee management to determine what activities were completed by the licensee following the discovery of foreign material in the CST. Based on the interviews, the team determined the following:

- Before entering the CST, senior management had implemented compensatory measures to declare the CST inoperable and align the AFW suction source to the essential service water system if significant foreign material was identified.

- During the morning of January 27, 2002, the licensee had evaluated the effect on the AFW system from foreign material in the CST. Even though the extent of the diaphragm seal degradation was not yet known, senior management concluded that the effect of foreign material on the AFW system was low due to the number of hours the AFW pumps had operated, the visual clarity of water in the CST, and the lack of debris on the floor of the CST.

- During the evening of January 27, 2002, the licensee removed the foreign material from the CST. Senior management was informed that the material had been removed and that the CST was clean.

- During the morning of January 28, 2002, the licensee believed that the removed material had been in the CST for an extended period of time. Senior management determined that the Teflon material was not an operability concern (at this time senior management had been incorrectly informed on several occasions that the Teflon material had a single tear). In addition, senior management believed that the foam was not an operability concern based on the run times for each of the AFW pumps.

- During the evening of January 28, 2002, senior management questioned engineering personnel about the Teflon fabric. Senior management was incorrectly informed that the area where the foam was missing was intact (i.e., single tear in material). Senior management determined that the Teflon material had probably been in the CST since construction.

- During the afternoon of January 29, 2002, the licensee discussed the results of inspection activities with the team. The licensee indicated that no inspections of the AFW system were planned for the near term. The team subsequently determined that the licensee had planned to inspect small diameter piping associated with the AFW pumps during the next regularly scheduled planned maintenance period for each AFW pump train.

- On January 30, 2002, the team viewed the video footage of the CST and degraded diaphragm seal with the plant manager. The team determined that the plant manager had not viewed the footage involving the degraded diaphragm seal. After viewing the video footage, the team and the plant manager questioned the validity of the information obtained from the licensee's staff regarding the as-found condition of the diaphragm seal. The plant manager then re-interviewed the diver and determined that the Teflon material did not have a single tear, but had jagged edges and was missing multiple pieces. Based on the information obtained from the diver, senior licensee management determined that the appropriate action would be to shutdown the plant and complete additional inspections of the CST and AFW system.

The team determined that the incorrect information provided by the licensee's staff to senior management delayed the initiation of the extent of condition review associated with the discovery of foreign material in the CST. Once initiated, the extent of condition review was thorough and provided assurances that the AFW system did not contain any further foreign material. The team determined that the failure of the licensee's staff to correctly report a significant condition adverse to quality to the appropriate levels of management in a timely manner was an additional example of the apparent violation of 10 CFR Part 50, Appendix B, Criterion XVI.

4.0 Contributing Causes

4.1 Operating Experience

a. Inspection Scope

The team reviewed industry operating experience information related to tank diaphragms to determine if the licensee applied the data appropriately. The review consisted of interviewing licensee personnel, searching operating experience databases, reviewing corrective action documents, reviewing the licensee's responses to operating experience information, and verifying licensee actions taken in response to applicable operating experience. The team's review satisfied the activities associated with AIT Charter Element 6, "Identify and assess the licensee's evaluation of applicable industry operating experience."

b. Observations and Findings

Information Notice 91-82

On December 18, 1991, the NRC issued Information Notice (IN) 91-82, "Problems with Diaphragms in Safety Related Tanks." NRC IN 91-82 reminded licensees that diaphragms in safety related tanks had finite service lives and could cause various safety hazards if they fail. On January 21, 1992, the licensee initiated Callaway Action Tracking System Item CATS 31040, "Generate PM for Regular Inspection of CST Cover," to ensure a maintenance activity to periodically inspect the CST diaphragm seal was generated. On February 10, 1992, the licensee issued a response to NRC IN 91-82 which specified that the licensee had experienced some problems with rubber diaphragm type tank seals and had initiated programs to inspect tank internals for degradation of diaphragms.

On September 15, 1999, the licensee initiated Callaway Corrective Action System Item CARS 199901955, "PM to Inspect CST Internal Cover Not Generated," in response to an NRC resident inspector question regarding the condition of the CST diaphragm seal. The licensee identified that Callaway Action Tracking System Item CATS 31040 had been closed without performing an inspection of the diaphragm seal. The team determined that the closure of Callaway Action Tracking System Item CATS 31040 without having completed an inspection may have contributed to the delay in identifying the degraded condition of the CST diaphragm seal and was an additional example of the apparent violation of 10 CFR Part 50, Appendix B, Criterion XVI.

The licensee contacted the seal vendor and was informed that the only expected degradation of the diaphragm seal would be wear of the outer Teflon skin covering the foam seal as it rubbed against the tank wall when level fluctuated. The licensee realized an inspection should be performed and initiated Generic Work Request G631231125, “Periodic Inspections of CST Diaphragm Seal,” to perform periodic seal inspections. After further review, the licensee determined that a specific inspection activity was more appropriate than a generic inspection activity and initiated Work Order W201820, “Inspect CST Floating Cover,” to inspect the seal in the Spring of 2000. At that time, the CST seal had not been inspected since its final closeout inspection in 1982. The team determined that the seal inspection activity per Work Order W201820 was rescheduled twice (Spring and Summer of 2000) before being performed in October 2000. The licensee’s basis for deferring the inspections was to allow enough time for completion of the seal inspection work. The team determined that the licensee’s basis for delaying the inspection did not fully consider the potential consequences of a degraded seal and was an additional example of the apparent violation of 10 CFR Part 50, Appendix B, Criterion XVI. In addition, this missed opportunity to promptly identify a condition adverse to quality represented an additional example of a significant human performance cross cutting issue involving the recognition of degraded conditions.

On October 17, 2000, the licensee performed a topside visual inspection of the CST diaphragm seal. The licensee did not thoroughly inspect the outer seal fabric which the vendor had stated one year earlier was vulnerable to wear failure. The team determined that the scope of the licensee’s inspection was inadequate to determine that the diaphragm seal was intact and was an additional example of the apparent violation of 10 CFR Part 50, Appendix B, Criterion XVI. In addition, this missed opportunity to promptly identify a condition adverse to quality represented an additional example of a significant human performance cross cutting issue involving the recognition of degraded conditions.

The team also determined that the licensee had initiated Preventive Maintenance Item P663567, “Inspect CST Cover,” to inspect the topside of the diaphragm seal on a 10-year periodicity. Preventive Maintenance Item P663567 did not include instructions to inspect the bottom side of the seal assembly. Therefore, future inspections may not have identified the degradation.

Significant Operating Experience Report 97-01

The team reviewed the licensee’s response to Significant Operating Experience Report 97-01, “Potential Loss of High Pressure Injection and Charging Capability From Gas Intrusion.” No deficiencies were identified.

4.2 Nitrogen Effect on Condensate Storage Tank Diaphragm Seal

a. Inspection Scope

The team reviewed the modifications to the CST that added and later modified a nitrogen sparging system to control dissolved oxygen. The team reviewed two modification packages; (1) Request for Resolution 04991, Revision A, "Permanent N2 for the Condensate Storage Tank," dated May 4, 1988, to replace the temporary tubing in CST by permanent connections; and (2) Restricted Modification Package 88-2016, Revision A, dated November 20, 1992, to install the permanent nitrogen sparger system in the CST. The documentation for the modification to add the temporary nitrogen tubing to the CST in 1986 was not available.

b. Observations and Findings

The licensee's evaluation of the modifications did not consider the effect of nitrogen on the CST floating diaphragm. Specifically, the location of the nitrogen piping and how the nitrogen would diffuse from the sparger and affect the floating diaphragm or the AFW pump available NPSH was not considered. The licensee concluded, without documentation, that the release of small quantities of nitrogen gas were insignificant, not regulated by any state or federal agency, and that no unreviewed environmental question existed.

There were no drawings of the temporary tubing or the permanent piping in the CST in the documentation provided by the licensee. There was also no documentation of any calculations performed to determine, based on the sparger design, the flow rate needed to saturate the tank water with nitrogen or the effect of nitrogen on the diaphragm seal.

4.3 Nitrogen Effect on Net Positive Suction Head (NPSH)

a. Inspection Scope

The team reviewed Calculation AL-10, "Determine the Available NPSH for the Auxiliary Feedwater Pumps," dated July 21, 1977, as revised in 1980; Calculation AL-13, "A System Model of the AFW System," dated September 14, 1995; and Calculation AL-24, "Determine the Effect of Dissolved Nitrogen on Available NPSH for the Auxiliary Feedwater Pumps," dated February 6, 2002, to determine if there was adequate NPSH for AFW Pump A.

b. Findings and Observations

The team identified a violation of 10 CFR Part 50, Appendix B, Criterion III, "Design Control," which involved the failure account for the effect of nitrogen on AFW pump NPSH.

Calculation AL-10 was completed for the CST and AFW system before the CST was modified to add a nitrogen sparging system to control dissolved oxygen. Prior to 1988, the amount of oxygen in the CST water was controlled by recirculating water to the main condenser hotwell. However, the licensee determined that this method of removing oxygen from the CST resulted in water temperatures during the summer months that could exceed the design temperature of the AFW system suction piping. To prevent the high temperature water, the licensee installed modifications to the CST to add a nitrogen sparging system.

The team determined that the evaluations for the modifications did not address the affect of the nitrogen saturated water on the pump tolerable volume fraction and the available NPSH for the AFW pumps. The tolerable volume fraction of gases is a measure of the quantity of free gases which can be passed by the pump without the gas volume affecting pump performance (i.e., reducing pump performance to the point of gas binding the pump). The NPSH required for a pump with a lower tolerable gas volume fraction will be smaller than the NPSH required for a pump with a higher tolerable gas volume fraction. NPSH is the minimum suction head required for a pump to operate. The team determined that the tolerable volume fraction for AFW Pump A was approximately 5 percent. The licensee determined that the expected volume of free nitrogen, based on the reduction of pressure from the CST to the pump impeller eye, was less than 5 percent.

On January 25, 2002, the licensee initiated Callaway Corrective Action System Item CARS 200200485, "Evaluate the Potential Effects of Dissolved Nitrogen on the Auxiliary Feedwater System," following the identification that nitrogen had not been accounted for in AFW pump NPSH calculations.

On February 6, 2002, the licensee completed Calculation AL-24 to address the effect of nitrogen on the available NPSH for the AFW pumps. Calculation AL-24 was reviewed by the team to determine if the assumptions were conservative and the calculated available NPSH was correct. The equations used by the licensee were from the following papers: (1) Daniel W. Wood, et. al., Proceedings of the 15th International Pump Users Symposium, "Application Guidelines for Pumping Liquids that have a Large Dissolved Gas Content," pages 91 through 98, dated March 1998, (2) Mao J. Tsai, Chemical Engineering, "Accounting for Dissolved Gases in Pump Design," dated July 26, 1982; and (3) C. C. Chen, Chemical Engineering, "Optimal System Design Requires the Right Vapor Pressure. Here's How to Calculate It," pages 106 through 112, dated October 1983.

Calculation AL-10, specified that the available NPSH for AFW Pump A was 28 feet, assuming the CST water level was at the suction of the AFW system. The available NPSH for AFW Pump A at the CST to essential service water system swap-over level was 35 feet. Calculation AL-10 did not account for dissolved nitrogen because the CST was not modified with a nitrogen sparger until 1988.

Calculation AL-24 included the effect of nitrogen saturated water, and assumed a minimum temperature of 50^{o}F, a 5 percent tolerable volume fraction of gas, and the CST to essential service water system swap-over elevation. The team reviewed Calculation AL-24 and determined that the reduction in available NPSH for AFW Pump A, due to the effect of the dissolved nitrogen in the CST, was approximately 11 feet.

10 CFR Part 50, Criterion III, "Design Control," required, in part, that the licensee implement design control measures for verifying or checking the adequacy of the design by the use of calculation methods. The team concluded that the licensee's identification that calculational methods failed to verify the adequacy of NPSH requirements for the AFW pumps was a violation of 10 CFR Part 50, Appendix B, Criterion III (05000483/0207-02). The team determined that the failure to account for nitrogen saturated water in the NPSH calculation for the AFW pumps was more than minor because there was a credible impact on safety in that the available margin of NPSH was reduced by 11 feet. Using Phase 1 of the Significance Determination Process, the team determined that the issue was of very low safety significance (Green) in that adequate available NPSH remained after accounting for the affect of dissolved nitrogen. Therefore, the availability of AFW pumps was not effected by the reduction in available NPSH margin.

4.4 Condensate Storage Tank Modification Corrective Actions

a. Inspection Scope

The team reviewed Request for Resolution 21798, Revision D, "Evaluate Permanent Removal of TAP01 Floating Cover," dated February 1, 2002, to ensure the licensee appropriately considered any negative consequences associated with the modification.

b. Observations and Findings

The team determined that members of the licensee's staff believed that the non-safety related CST did not have a function important to safety. The equipment qualification impact review section of the licensing impact review form required that an individual determine if the activity involved any safety-related structure, system, or component. The individual was not required to state if the non-safety related structure, system, or component had a safety function or if it was important to safety. The team noted that there was a probabilistic risk assessment (PRA) review section on the licensing impact review form which questioned if there was a potentially PRA-significant change to a plant system.

The team noted that if the originator of the licensing impact review form did not understand the safety function of the non-safety component, the answer to the question about a potential PRA-significant change to a plant system may be incorrect. In this case, the reviewer did not consider the change PRA-significant. The review was subsequently re-evaluated by the PRA group. The team determined that the PRA staff appropriately determined that the modification to remove the diaphragm seal was not risk significant.

The team interviewed several members of the licensee's staff and was informed that evaluations associated with non-safety related equipment did not receive the same level of rigor as evaluations associated with safety-related equipment. The team determined from these interviews that this lack of rigor existed even in those instances in which the non-safety component had a function which was important to safety.

The licensee also determined that not properly acknowledging the relationship between the non-safety related CST and the safety-related AFW pumps led to non-conservative decisions that may have contributed to December 3, 2001, event. The licensee planned to address these concerns by bringing a heightened awareness to the plant organization through group discussions or training.

4.5 Condensate Storage Tank Seal Maintenance

a. Inspection Scope

The team reviewed design information associated with the expected service life of the diaphragm seal and the frequency of maintenance and inspection activities.

b. Observations and Findings

The team determined that not all of the original design specifications for the diaphragm seal were readily available to the licensee during its investigation of the failure of the diaphragm seal. CST Design Specification 10466-M-109 (Q), Section 5.27.4.3, referenced a negotiated seal life guarantee and warranty period but did not provide any actual life expectancy. The licensee was not able to produce any documentation regarding the seal life or warranty information referenced in the design specifications. The team determined that the lack of information may have contributed to a decrease in the sensitivity for the need to complete periodic inspection and maintenance activities on the diaphragm seal.

4.6 Operability Evaluations

a. Inspection Scope

The team reviewed three operability evaluations associated with the CST and AFW system to determine the adequacy of the licensee's review of degraded but operable conditions. The team also compared Generic Letter 91-18, Revision 1, "Information to Licensees Regarding NRC Inspection Manual Section on Resolution of Degraded and Nonconforming Conditions," to the licensee's implementing procedures for operability evaluations. The team's review satisfied a portion of the activities associated with AIT Charter Element 3, "Assess the timeliness and effectiveness of the licensee's evaluation of potential AFW common cause failure stemming from the degraded condensate storage tank floating diaphragm."

b. Observations and Findings

The team identified several weaknesses associated with the licensee's corrective action and operability evaluation programs.

Procedure APA-ZZ-00500, "Corrective Action Program," Section 3.1.1, specified that all personnel are responsible for the immediate notification of the shift supervisor upon discovery of a condition that they "believe" to have an immediate impact on nuclear, plant, or personnel safety. Section 5.3.1.2 specified that if the condition discovered is "believed" to have an immediate impact on operability, reportability, plant or personnel safety, then the originator is to immediately notify the shift supervisor. The team interviewed personnel assigned to the corrective action group and determined that equipment deficiencies did not require the notification of the shift supervisor if the individual believed that equipment operability was not immediately affected. The team also interviewed the assistant operations superintendent and determined that his expectations were for personnel to notify the shift supervisor of any equipment deficiency. The team determined that the guidance and expectations regarding the notification of the shift supervisor of equipment deficiencies were not consistently implemented. In addition, the team determined that the opportunity for licensed personnel to assess operability for degraded equipment conditions may not occur if the originator (possibly non-licensed individual) believed that an operability concern did not exist. The team determined that the failure to notify the shift supervisor of deficiencies associated with plant equipment could have a credible impact on safety. For example, the shift supervisor was not notified of the significant condition adverse to quality described in Callaway Corrective Action System Item CARS 200200264, “Foreign Material Found in the AL System” and Callaway Corrective Action System Item CARS 200200485, “Evaluate the Potential Effects of Dissolved Nitrogen on the Auxiliary Feedwater System.” The safety significance associated with foreign material in the AFW system and CST is described in Section 7.

Procedure APA-ZZ-00500, Attachment 7, “OPER Disposition,” provided guidance for completing operability evaluations. The guidance consisted of eight steps which involved:

- reviewing documentation to understand the issue, assuring the correct individual was assigned to review the issue,
- investigating the issue,
- assigning actions to other individuals if necessary,
- preparing a response,
- entering correct information,
- attaching supporting information, and
- closing the OPER action.

The team determined that there were no references in Attachment 7 to Generic Letter 91-18. Consequently, the licensee’s operability evaluation program did not provide the following:

- Guidance to aid the reviewer in determining when a safety evaluation was required to be considered.
- A requirement for a licensed operator to be notified when an operability evaluation was being or had been performed.

- Guidance on the amount of time required to complete an operability evaluation.
- Guidance on the required level of review of an operability evaluation.
- Guidance for the completion of safety evaluations associated with compensatory measures.
- Guidance for the periodic reviews of open operability evaluations.

The team determined that the failure to have an adequate program for processing operability evaluations could have a credible impact on safety. For example, the operability evaluations for Callaway Corrective Action System Item CARS 200200264, “Foreign Material Found in the AL System”; Callaway Corrective Action System Item CARS 200200485, “Evaluate the Potential Effects of Dissolved Nitrogen on the Auxiliary Feedwater System”; and Callaway Corrective Action System Item CARS 200200489, “Complete an ‘Operability Evaluation’ on the CST Due to the Existence of the Foam Pieces” did not provide an adequate basis for continued operability of the AFW system and the CST. The safety significance associated with these operability evaluations is described in Section 7.

Callaway Corrective Action System Item CARS 200200264, “Foreign Material Found in the AL System,” dated January 15, 2002, involved the discovery of foam in the AFW Pump A seal water cooling line. The shift supervisor was not notified of this significant condition adverse to quality. Callaway Corrective Action System Item CARS 200200264 was assigned a Significance Level of 3 (no onsite review committee evaluation required). The assigner (acting system engineering mechanical supervisor) assigned the operability evaluation to himself. The operability evaluation had a required completion date of February 16, 2002, and was completed on January 17, 2002. The required completion date was well beyond the allowed outage time associated with the AFW and CST Technical Specifications, which were 72 hours and 7 days, respectively. No peer or supervisory review of the finished operability evaluation was completed. Operations personnel were not provided the opportunity to review the completed operability evaluation. The team determined that the operability evaluation did not adequately assess the extent of condition. Specifically, no assessment of the source of the foreign material or where additional foreign material could be located was performed. This failure to adequately assess the presence of foreign material in the AFW system is documented in Section 3.2 as an example of an apparent violation of 10 CFR Part 50, Appendix B, Criterion XVI.

Callaway Corrective Action System Item CARS 200200485, “Evaluate the Potential Effects of Dissolved Nitrogen on the Auxiliary Feedwater System,” dated January 25, 2002, involved the identification by the licensee that the effect of dissolved nitrogen on the AFW system had not been considered. The shift supervisor was not notified of this significant condition adverse to quality. Callaway Corrective Action System Item CARS 200200485 was assigned a Significance Level of 3 (no onsite review committee evaluation required). The operability evaluation had a required completion date of February 16, 2002, and was not completed before the plant shutdown on January 31, 2002. The required completion date was well beyond the allowed outage time associated with the AFW and CST Technical Specifications, which were 72 hours and 7 days, respectively. The team determined that the response to the operability evaluation was untimely in that the plant continued to operate beyond the allowed outage time associated with the AFW system without an assessment of the potential safety significance of the impact dissolved nitrogen had on the CST and AFW system. The failure to account for the affect of nitrogen on available NPSH is documented in Section 4.3 as a noncited violation of 10 CFR Part 50, Appendix B, Criterion III.

Callaway Corrective Action System Item CARS 200200489, “Complete an ‘Operability Evaluation’ on the CST Due to the Existence of the Foam Pieces,” dated January 27, 2002, involved the discovery of foam in the CST. The shift supervisor was notified of the condition. Callaway Corrective Action System Item CARS 200200489 was assigned a Significance Level of 2 (onsite review committee evaluation of the root cause required). The operability evaluation had a required due date of January 27, 2002, and was completed as required. The licensee determined that the AFW system was operable because: (1) the material identified in the tank was fragile and not able to clog an AFW pump orifice, (2) an insufficient flow velocity existed in the CST to cause the identified material to enter the AFW system, (3) the isolation of secondary plant systems returning to the CST (minimize recirculation of the CST contents), and (4) successful completion of AFW pump testing. The team determined that inadequate information provided by the licensee’s staff to senior management delayed the initiation of the extent of condition review associated with the discovery of foreign material in the CST. Once initiated, the extent of condition review was thorough and provided assurances that the AFW system did not contain any foreign material. The failure to communicate information regarding significant conditions adverse to quality is documented in Section 3.2 as an example of an apparent violation of 10 CFR Part 50, Appendix B, Criterion XVI.

Corrective Actions

The licensee planed to institute a series of programmatic and procedural enhancements to improve weaknesses in the operability evaluation program. These enhancements included:

- Adding an operability evaluation form to the Callaway Corrective Action System Item procedure.
- Attaching completed operability evaluation forms to the associated Callaway Corrective Action System Item.
- Requiring operability evaluation forms to specify compensatory actions.
- Requiring a review of operability evaluations.
- Supplementing operability evaluation guidance with information from Generic Letter 91-18.
- Requiring shift supervisor approval for completed operability evaluations.
- Tracking operability evaluations with their associated Callaway Corrective Action System Item.

- Adding criteria for timely completion of operability evaluations.
- Implementing timely root cause evaluations for Significance Level 1 and 2 events.

5.0 Extent of Condition Review

a. Inspection Scope

The team reviewed documentation to determine to what extent the degraded CST diaphragm seal may have had on other systems, structures, or components. The review included visual inspections of the degraded seal and examination of the foreign material removed from the CST and AFW Pump A. The team's review satisfied the activities associated with the AIT Charter Element 4, "Determine to what extent the degraded CST floating diaphragm could potentially impact plant equipment. In addition to the AFW system, this review should assess the potential impact on any other components and systems, which may be affected."

b. Observations and Findings

The licensee had seven tanks with diaphragm seal devices. Six of those tanks used a rubber seal assembly and the CST used the rigid diaphragm seal designed by Conservaflote. The six tanks designed with rubber type diaphragm seals have had periodic inspections performed in the past and were not expected to fail before signs of degradation were identified by the licensee. The most risk significant tank (reactor makeup water tank) had been inspected on a 5-year periodicity and the diaphragm was replaced in 1998. The team determined that the same or similar condition did not exist in other tanks at the facility.

The licensee performed laboratory analysis of the foam in order to determine the potential effect on the steam generators. The analysis concluded that the foam was of a polyurethane type where degradation (melting) commenced at 428°F and significant degradation occurred at 513°F. As a result of the analysis and the temperature environment in the steam generators at the time of the event, the licensee determined that any foam entering the steam generators would have quickly degraded and become diluted in the steam generator inventory. The team determined that there were no apparent effects from the foam on the steam generator internals or instrumentation.

6.0 Quality Assurance Review

6.1 Review of the Quality Assurance Aspects of the Event

a. Inspection Scope

The team interviewed personnel to determine the extent of quality assurance (QA) personnel involvement in the resolution of the failure of AFW Pump A. The team's review satisfied the QA activities portion of Charter Element 5, "Identify any human factor, procedural or quality assurance deficiencies that may have contributed to the condition."

b. Observations and Findings

The team interviewed the QA manager and determined that QA did not participate in the event response team meeting for the December 3, 2001, event. In addition, the team determined that the licensee did not notify QA when event response team meetings were conducted. Consequently, QA was not provided the opportunity to oversee the process.

The team also determined that no one from QA was specifically assigned to oversee the resolution of the root cause analysis and that QA personnel provided limited oversight of the investigation into the failure of AFW Pump A. Specifically, QA's involvement was limited to the following: (1) The Callaway Corrective Action System Item was reviewed as part of the daily screening of corrective action program documents. (2) In early December 2001, a print-out of the AFW flow control valve response and NRC Bulletin 88-04, "Potential Safety-Related Pump Loss," was provided to the corrective action group facilitator assigned to assist in the development of the root cause (the facilitator was not directly involved in the investigation of the failure of AFW Pump A until mid-to-late January 2002). Bulletin 88-04 involved minimum flow line issues associated with safety-related pumps and was not related to the failure of AFW Pump A. (3) A review of the evaluation for returning AFW Pump A to an operable status was completed. (4) Assessment activities associated with the entry into the CST were completed.

6.2 Quality Assurance Audits of Foreign Material and Operating Experience

The licensee did not specifically perform audits of the foreign material and operating experience programs. Instead, the licensee audited the foreign material and operating experience aspects of whatever audits and assessments were completed. The licensee provided copies of audits that contained the key words "foreign material" or "operating experience." The team did not identify any abnormal trends in the foreign material or operating experience programs.

7.0 Risk Significance of Event

a. Inspection Scope

The team reviewed the licensee's risk analysis associated with the failure of AFW Pump A. The issue was determined to be more than minor because the on-demand failure of AFW Pump A had an actual impact on plant safety. In addition, the degraded condition of the diaphragm seal could have affected the availability of the AFW system. The team completed an NRC Manual Chapter 0609, "Significance Determination Process," Phase 1 analysis of the failure of AFW Pump A. The SDP Phase 1 screening process required that an SDP Phase 2 analysis be performed because the finding represented an actual loss of a train of the AFW system. The team also completed an SDP Phase 3 analysis in addition to the Phase 2 analysis to obtain a better understanding of the increase in core damage frequency (CDF) stemming from the identified performance issues. The CDF is the expected frequency of a core damage event. The team's review satisfied the risk assessment activities associated with AIT Charter Element 2, "Review the licensee's root and probable cause determination for independence, completeness, and accuracy, including the licensee's assessment of the risk associated with the condition," and a portion of Charter Element 3, "Assess the timeliness and effectiveness of the licensee's evaluation of potential AFW common cause failure stemming from the degraded condensate storage tank floating diaphragm."

b. Observations and Findings

Potential Impact of Safety Functions

A failure of the AFW system had a significant impact on the decay heat removal safety function. The AFW system was the third most risk important system for the Callaway Plant.

Potential for Common Cause Failure of the AFW System

The team inspected the condition of the diaphragm seal once it had been removed from the CST to determine the extent of the condition of the degraded seal. The team also interviewed various members of the licensee's staff to evaluate the effect the degraded seal could have on systems supplied by the CST.

The team determined that the degradation of the seal was limited to a 71-inch circumferential section of the diaphragm. The degraded portion of the diaphragm seal was located above the single suction source of the AFW system (See Figure 4). The following table provides a listing of the missing foam portions of the seal.

Degraded Diaphragm Seal Inventory	
Amount (length/height/width)	Location
2 inch x 3 inch x 8 inch	CST Sump
11.5 inch x 3 inch x 8 inch	Removed by diver to complete seal repair
12 inch x 3 inch x 8 inch	CST Sump
20.5 inch x 3 inch x 8 inch	Total amount of unaccounted foam.
25 inch x 3 inch x 8 inch	Hanging from diaphragm and removed by diver.

The team determined that the amount of unaccounted foam could have been one or more pieces totaling 20.5 x 3 x 8 inches of material. The foam could have entered the suction of the AFW system as a single piece of foreign material or as multiple pieces of foreign material. The team determined that the proximity of the degraded seal location to the suction of the AFW system increased the likelihood that a piece of foam could enter the AFW system. The team also determined that the length and configuration of the foam could affect the operation of the AFW system following an event.

The licensee's lower bound risk analysis of the degraded diaphragm seal assumed there was no potential for common cause failure of the AFW system or multiple AFW pumps because the AFW pump would have recovered without operator action. The licensee's upper bound risk analysis of the degraded diaphragm seal assumed that the two pieces of foam located in the CST sump, plus one additional piece of foam, could affect the AFW pumps for a period of 1.8 months. After 1.8 months, only one piece of foam was assumed to exist. Specifically:

- The licensee determined that the 25-inch long section of foam removed by the diver could not have fallen into the CST before January 25, 2002. Specifically, the section of removed foam was attached to a 6-foot section of foam and the diver was unable to pull the foam away from the masonite board or tear the foam. Additionally, the licensee believed that the clearances between the CST wall and the floating diaphragm were sufficient to prevent the foam from being pinched off.

- The licensee determined that the two pieces of foam found in the sump would not have entered the AFW suction piping once the specific gravity exceeded 1.03. The specific gravity of the foam attached to the diaphragm was approximately 1.0. The specific gravity of the water saturated foam in the CST sump was approximately 1.31. The depth of the CST sump was approximately 3 feet. The licensee determined that a linear velocity of approximately 1.5 feet per second would be required to lift water saturated foam from the bottom of the CST. The actual linear flow velocity across the CST sump was determined to be less than 1 foot per second. The licensee chemically analyzed the foam in the CST sump and determined that the material had undergone hydrolytic decomposition, indicating that the foam had been in the sump for an extended duration. The chemical analysis was supported by the recognition that biological materials had permeated the entire volume of the foam.

- The licensee evaluated the effect of a single 20.5 inch long piece of foam on the AFW system. The licensee determined that the elasticity of the foam would have prevented it from obstructing the suction piping at the CST vortex breaker or the manual suction isolation valve. The licensee also determined that a single piece of foam would not have torn into multiple pieces as the foam traveled from the CST to the suction of an AFW pump.

The team determined that there was a wide variance in the possible effects foam could have on AFW system performance. Consequently, the team determined that there was an increased likelihood for common cause failure of the AFW system due to foam from the degraded diaphragm seal. Specifically: (1) multiple pieces of foam could have become dislodged from the diaphragm seal. The multiple pieces could have affected one or more AFW pumps following a demand signal. (2) A single piece of foam could have separated into multiple pieces as it traversed the AFW suction piping and affected one or more AFW pumps.

Recovery of AFW Pump A

The licensee hypothesized that the foam was extruded through the pump impeller and that the pump would have self-recovered within a few additional minutes had operations personnel not secured the pump. The licensee indicated that the pump was recovering and eventually would have delivered design flow for the following reasons:

- AFW Pump A motor current was increasing during the event.
- AFW Pump A pump was vented for approximately 15 seconds allowing gas to escape. No steam was present during the venting.
- AFW Pump A was started successfully following the pump vent.

The licensee determined that the pump motor amperage increase during the event indicated that AFW Pump A was recovering. The team determined that the motor current increase from 42 to 46 amps, during the 10 minutes the pump operated, did not support a conclusion that the pump would have recovered without operator intervention. The team noted that the current increase could have been the result of the rise in temperature on the outboard stuffing box which may have increased the frictional forces on the shaft rotor due to the contact with the dry stuffing box packing material. Moreover, trend data indicated that there was no corresponding increase in pump discharge pressure or flow.

The team also noted that as a result of operating the pump in a partially air-bound condition, the pump experienced some minor hydraulic degradation, which required the licensee to establish new baseline pump characteristics to satisfactorily complete the required surveillance tests (following the event, AFW Pump A could not attain the required minimum flow). This information further indicated to the team the significance of the air-binding event and the potential that the pump may not have been able to self-recover. In addition, had operations personnel not de-energized the pump, the potential existed for additional degradation of AFW Pump A.

The team determined that the successful venting and starting of the pump indicated that the potential existed for operations personnel to recover a failed AFW pump. Two independent flow paths existed for supplying water to the outboard packing housing. Even though the seal water cooling line was obstructed with foam, the normal leakage along the pump shaft should have been sufficient to provide lubricating flow to the outboard packing housing. The team determined that the licensee's human error probability calculation for recovery of an AFW pump was appropriate. The analysis considered the available time to diagnose the condition and take actions to restore the pump. The team also determined that operations personnel possessed the requisite skills to successfully complete a pump vent. Therefore, the team determined that the licensee had appropriately determined that the potential for successful recovery of a failed AFW pump was 0.95.

Review of Licensee's Risk Calculations

The licensee's preliminary lower bound risk analysis assumed that; (1) only one pump would be affected (no potential for common cause failure), (2) the affected pump would self-recover, (3) the likelihood that a piece of foam large enough to affect the system would enter the AFW suction piping was 0.5, and the likelihood that an operator would fail the pump as part of a recovery action was 2.9E-3. Based on these assumptions, the licensee determined that the increase in core damage frequency (CDF), excluding external events and flooding, was approximately 8E-7/year for a 100 percent capacity factor and 6.8E-7/year for an 85 percent capacity factor. The team determined that the 85 percent capacity factor represented the actual at-power operating history of the facility. In addition, the team determined that for the 15 percent shutdown interval, the licensee did not credit the use of the AFW system while the residual heat removal system was operating with the plant in Modes 4, 5, and 6.

The licensee's upper bound case assumed a potential for common cause failure existed for the first 1.8 months and only a single piece of foam for the remaining 10.2 months. The licensee based the 1.8 month interval on their determination that the two pieces of foam found in the CST would have entered the sump within 1.8 months. In addition, the licensee assumed that the human error probability for recovery of a failed AFW Pump was approximately 0.05. The licensee's upper bound result of the increase in CDF, excluding external events and flooding, was 5.53E-6/year for a 100 percent capacity factor and 4.7E-6/year for an 85 percent capacity factor.

The licensee's average test and maintenance Probabilistic Safety Assessment (PSA) model used a loss of offsite power (LOOP) initiating event frequency of 3.9E-2/year (Electric Power Research Institute TR 110398). The licensee's next PSA model update planned to use a revised LOOP frequency of 2.2E-2/year. The revised LOOP frequency used the values in EPRI 1000158 (2.8E-2) minus the contribution from coastal LOOP events and shut-down LOOP events. In addition, the licensee completed a Bayesian update to reflect plant specific values associated with a LOOP event. Specifically, the licensee has not had a LOOP event during the previous 17 years of plant operation. The Bayesian update further reduced the LOOP frequency to 2.2E-2/year. The new LOOP frequency reduced the baseline average test and maintenance CDF from 2.45E-5/year to 1.59E-5/year.

NRC Phase 2 Risk Assessment

The team completed a preliminary significance determination using the SDP Phase 2 process described in NRC Manual Chapter 0609, "Significance Determination Process." Two analyses were completed. The first analysis assumed that AFW Pump A was unavailable for 1 year without any credit for recovery actions. The second analysis assumed that all three AFW pumps were unavailable for 1 year without credit for recovery actions. Table 2, "Initiators and System Dependency for Callaway Nuclear Generating Station, Unit 1," of the Callaway Plant Phase 2 site specific notebook required that all initiating event scenarios except a loss of service water and a large break loss of coolant accident be evaluated for findings affecting a motor driven AFW pump and that all initiating event scenarios except a large break loss of coolant accident be evaluated for findings affecting the turbine driven AFW pump.

The team analyzed 28 sequences using the site specific notebook and determined that the dominate initiating event scenarios for a failure of AFW Pump A were transients without the power conversion system and loss of offsite power. This case produced a preliminary significance determination of substantial (Yellow).

The team analyzed 45 sequences using the site specific notebook and determined that the dominate initiating event scenarios for a failure of all AFW Pumps were transients with and without the power conversion system, loss of offsite power, and loss of a vital dc bus. This case produced a preliminary significance determination of high (Red).

The team determined that an SDP Phase 3 analysis should be performed because the results of the Phase 2 analysis may have been overly conservative. Specifically, mitigation credit was not applied for recovery of a failed AFW pump, all AFW pumps were assumed to fail in order to account for a potential common cause failure mode, and the site specific notebook had not accounted for changes in the licensee's PSA model.

NRC Phase 3 Risk Assessment

The team requested that the licensee use their PSA model to calculate the change in CDF for several combinations of AFW pump failures due to common cause with various recovery probabilities. The duration for all the combinations was 1 year because no information was provided which suggested that the diaphragm seal was degraded for an interval of less than 1 year. The first variable involved adjusting the likelihood that a piece of foam from the diaphragm entered the suction of the AFW system to 0.25, 0.5, and 1.0. The second variable involved adjusting the recovery probability of a failed AFW pump to 0.05, 0.20, and 1.0. The third variable accounted for a change in the licensee's capacity factor from 100 to 85 percent. The team determined that the 85 percent capacity factor represented the actual at-power operating history of the facility.

The lower bound results assumed the duration was 1 year, a potential common cause failure of the remaining two AFW pumps, the likelihood that a piece of foam from the diaphragm entered the suction of the AFW system was 0.25, the recovery probability of a failed AFW pump was 0.05, and the capacity factor was 85 percent. The increase in CDF, excluding external events and flooding, was approximately 2.1E-6/year.

The upper bound results assumed the duration was 1 year, a potential common cause failure of the remaining two AFW pumps, the likelihood that a piece of foam from the diaphragm entered the suction of the AFW system was 1.0, the recovery probability of a failed AFW pump was 0.2, and the capacity factor was 100 percent. The increase in CDF, excluding external events and flooding, was approximately 1.1E-5/year.
The team's final determination of the safety significance of the degraded CST diaphragm seal was based on the following assumptions:

(1) An 85 percent capacity factor. In addition, the team determined that for the 15 percent shutdown interval, the licensee did not credit the use of the AFW system while the residual heat removal system was operating with the plant in shutdown Modes 4, 5, and 6.

(2) The revised LOOP frequency of 2.2E-2/year.

(3) A potential for common cause failure of the remaining two AFW pumps. The use of the nominal fail-to-run probability associated with the remaining AFW pumps was considered inappropriate in that there was an increased likelihood that foam could affect an AFW pump. Therefore, the team, increased the failure probability of the remaining motor-driven pump from 4.2E-3 to 0.1 and the turbine-driven pump from 2.4E-3 to 0.1.

(4) The duration of 1 year. No information was provided which suggested that the diaphragm seal was degraded for an interval of less than 1 year.

(5) The likelihood of 0.50 that a piece of foam which separates from the diaphragm enters the AFW system. Two pieces of foam totaling 14 inches in length were identified in the CST sump. This provided information to suggest that some of the foam material would not enter the AFW suction piping.

(6) The potential for successful recovery of a failed AFW pump of 0.95. The NRC analysts' determined that the licensee's human error probability calculation for recovery of an AFW pump was appropriate. The steam generator dryout time for a loss of all feedwater was approximately 1 hour. Adequate time existed to diagnose the event and take actions to restore at least 1 AFW pump. The team determined that operations personnel possessed the requisite skills and knowledge to successfully complete a pump vent. In addition, there were no environmental or human factor issues which could have affected the ability of operations personnel to vent and fill an AFW pump.

Given the above assumptions, the team determined that the increase in CDF, excluding external events and flooding, was approximately 4.3E-6/year. The initiating events with the greatest contribution to core damage involved a loss of offsite power, loss of service water, and loss of dc power. For the loss of offsite power initiating events, the dominant sequences involved a failure to recover ac power within 1 hour, a failure of both emergency diesel generators, and a failure of the turbine driven AFW pump. For the loss of service water initiating event, the dominant sequences involved a failure to recover service water and a failure of the turbine driven AFW pump. For the loss of dc power initiating event, the dominant sequences involved a failure of the turbine driven AFW pump, the motor driven AFW pumps, charging pumps, and residual heat removal pumps.

Consideration of External Events and Flooding

The licensee did not have a PSA model which integrated internal, external, and flooding events. The contribution from seismic events was negligible because the licensee had adequately resolved the vulnerabilities identified during the completion of their seismic margins analysis. The CDF associated with fire events was approximately 8.9E-6/year. The CDF associated with flooding events was approximately 6E-6/year.

The AFW system was the third most risk important system for the Callaway Plant internal PSA model. The team reviewed the licensee's Individual Examination of External Events document and determined that the AFW system supported the decay heat removal critical safety function in each of the licensee's external event analyses. The team noted that the percent increase in CDF for the internal events PSA model (4.3E-6/1.59E-5) was approximately 27 percent. Because of the importance of the AFW system for both the internal and external event models, the team qualitatively determined that there was some modest increase in risk associated with the consideration of external events. The team determined that the increase due to external events would not likely be sufficient for the performance deficiency to be characterized as having substantial safety significance (Yellow).

Large Early Release Frequency

The team determined that the contribution from the failure of the AFW system had a negligible impact on the large early release frequency. The team reviewed the dominate large early release frequency sequences affected by failures of the AFW system and determined that the increase was less than 1E-7/year. The dominate sequences involved a steam generator tube rupture with a failure to isolate the affected steam generator and a failure to establish either main feedwater or auxiliary feedwater flow.

Uncertainty

The mean values for the licensee's original internal events PSA model, which included flooding, was 1.95E-5. The 95th percentile of the PSA model was 4.16E-5 and the 5th percentile of the PSA model was 8.51E-6. Given the relatively narrow range between the 5th and 95th percentiles, the team determined that it was appropriate to use the point estimates derived from the PSA model quantifications without an additional adjustment to account for uncertainty.

Conclusions

The team determined that the preliminary safety significance of the degradation of the CST diaphragm seal was low to moderate (White). Specifically, the estimated increase in CDF was greater than or equal to 4.3E-6/year and less than 1E-5/year, assuming an 85 percent capacity factor, the revised LOOP frequency, an increased likelihood that a common cause failure could occur, a 1-year duration for the condition, the likelihood that a piece of foam which separates from the diaphragm enters the AFW system at least 50 percent of the time, and the potential for the affected AFW pumps to be recovered at least 95 percent of the time.

8.0 Overall Adequacy of the Licensee's Response

a. Inspection Scope

The team assessed the observations and findings identified during the inspection in order to complete an assessment of the overall adequacy of the effectiveness of the licensee's corrective actions in response to the failure of AFW Pump A. The team's review satisfied AIT Charter Element 8, "Review the overall adequacy of the licensee's response to the failure of the AFW pump."

b. Observations and Findings

The team determined that the licensee missed several opportunities to promptly identify and correct a risk significant condition involving the degraded condition of the CST diaphragm seal. The team also determined that the multiple failures of the licensee to identify the degraded CST diaphragm seal was a significant human performance cross cutting issue involving the recognition of degraded conditions.

Quality assurance personnel were not actively involved in providing oversight of the event review team and root cause investigation process. The event review team process did not ensure that statements were obtained from all personnel involved in the event. The corrective action program did not include guidance or expectations on the assignment of appropriate resources to review the highest classification of significant conditions adverse to quality. Minimal resources were assigned to the root cause investigation and may have contributed to the delay in identifying the degraded CST diaphragm seal. Based on interviews with the licensee's staff and a review of Procedure APA-ZZ-00500, "Corrective Action Program," the team determined that licensed operators were only notified of equipment deficiencies if the individual discovering the condition believed there was an immediate impact on nuclear, plant, or personnel safety. Consequently, the potential existed for operability decisions to be made by non-licensed personnel. The operability evaluation program did not implement the guidance provided in NRC Generic Letter 91-18.

9.0 Exit Meeting Summary

On February 27, 2002, the team presented the inspection results to Mr. G. Randolph and other members of his staff at a public exit meeting held at the Callaway Plant.

ATTACHMENT 1

SUPPLEMENTAL INFORMATION

KEY POINTS OF CONTACT

Licensee

R. Affolter, Vice President Nuclear
J. Blosser, Manager, Regulatory Affairs
S. Bond, Supervisor, Design Engineering
K. Connelly, Engineer, Regulatory Affairs
J. Laux, Manager, Quality Assurance
J. McGraw, Superintendent, Nuclear Engineering
T. Moser, Superintendent, System Engineering
G. Randolph, Senior Vice President and Chief Nuclear Officer
M. Reidmeyer, Supervisor, Regional Regulatory Affairs
M. Taylor, Manager, Nuclear Engineering
M. Waltz, Engineer, Regulatory Affairs
R. Wink, System Engineer
W. Witt, Plant Manager

NRC

L. Ellershaw, Senior Reactor Inspector
M. Franovich, Reactor Analyst
I. Jung, Reactor Analyst
P. Wilson, Senior Reactor Analyst
Y. Huang, Mechanical Engineer

ITEMS OPENED, CLOSED, AND DISCUSSED

Opened

05000483/0207-01	APV	Failure to promptly identify and correct a significant condition adverse to quality.

Opened and Closed

050-00483/0207-02	NCV	Failure to verify calculational methods.

DOCUMENTS REVIEWED

The following documents were selected and reviewed by the inspectors to accomplish the objectives and scope of the inspection and to support any findings:

Audit and Assessment Reports

Assessment Report AP01-005 and SA-QA-001, “Access Adequacy and Implementation of the Optimized Audit Process,” July 2, 2001

Audit Report AP00-008, “Fourth Quarter 2000 Quality Assurance Audit Report,” January 11, 2001

Audit Report AP01-001, “First Period 2001 Quality Assurance Report,” June 26, 2001

Audit Report AP01-002, “Second Period 2001 Quality Assurance Audit Report,” October 2, 2001

Audit Report AP01-006, “Quality Assurance Audit of the Training, Qualification, and Performance of Nuclear Division Personnel, February 2, 2002

Audit Report AP98-017, “Quality Assurance Audit of Callaway Cycle 10 Reload Design and Safety Analysis,” February 1, 2002

Surveillance Report SP98-001, “Self Assessment of the FSAR Review Effort, Callaway Plant,” February 1, 2002

Surveillance Report SP98-016, “A Safety Injection Outage,” February 1, 2002

Surveillance Report SP99-023, “Spent Fuel Pool (SFP) Re-rack Modification, CMP97-1016,” February 2, 2002

Surveillance Report SP99-013, “Spent Fuel Pool Rerack Modification,” February 2, 2002

Calculations

Calculation AL-10, “Determine the Available NPSH for the Auxiliary Feedwater Pumps,” July 21, 1977

Calculation AL-13, “A System Model of the AFW System,” September 14, 1995

Calculation AL-24, “Determine the Effect of Dissolved Nitrogen on Available NPSH for the Auxiliary Feedwater Pumps,” February 6, 2002

Corrective Action Program Documents

CARS 199901955, “PM to Inspect CST Internal Cover Not Generated”

CARS 200001900, “B MDAFP Run Stopped Due to Lack of Discharge Flow Indication”

CARS 200107423, “Auxiliary Feedwater System Event Review”

CARS 200200264, “Foreign Material Found in AL System”

CARS 200200485, “Evaluate the Potential Effects of Dissolved Nitrogen on the Auxiliary Feedwater System,” January 25, 2002

CARS 200200489, “Complete an ‘Operability Evaluation’ on the CST Due to the Existence of the Foam Pieces”

CARS 200200669, “Flow Rate on the B MDAFP Miniflow Line was Lower Than Expected”

CATS 31040, “Generate PM for Regular Inspection of CST Cover”

Maintenance Documents

Generic Work Request G631231125, “Periodic Inspections of CST Diaphragm Seal”

Preventive Maintenance Item P663567, “Inspect CST Cover”

W201820, “Inspect CST Floating Cover”

W220254, “Replace Rotating Element on ‘A’ MDAFP”

W682227, “Suction Piping Inspection”

W686916, “Camera and Diver Inspection of CST”

W687231, “‘A’ MDAFP Discharge Piping Inspection”

W687232, “‘B’ MDAFP Discharge Piping Inspection”

W687233, “TDAFP Discharge Piping Inspection”

W202393, “CST Seal Inspection”

Miscellaneous Documents

C. C. Chen, Utwin Engineers and Constructors, Inc., Chemical Engineering, “Optimal System Design Requires the Right Vapor Pressure. Here’s How to Calculate It,” pages 106 through 112, October 1983

Chemir/Polytech Laboratory Report, Job 39979, January 28, 2002

CST System Flow Diagram, M-01AP01, Revision E

CST Inspection Document, System Release Exception Form Item Number AP-015, July 15, 1982

Conservatek Design Drawing, 43-D2, Revision 1

CST Design Specification No. 10466-M-109(Q)

Daniel W. Wood, et. al., Proceedings of the 15th International Pump Users Symposium, "Application Guidelines for Pumping Liquids that have a Large Dissolved Gas Content," pages 91 through 98

Dominion Engineering, "Auxiliary Feed Pump Event," January 25, 2002

EPRI TR-114612-V2, "Pump Troubleshooting," April 2000

INPO SOER 97-01, "Potential Loss of High Pressure Injection and Charging Capability From Gas Intrusion"

Mao J. Tsai, Techon International, Inc., Chemical Engineering, "Accounting for Dissolved Gases in Pump Design," July 26, 1982

Report UOTH 01-0047, "Event Review Meeting Minutes: High Main Turbine Vibration, AFAS, and No Flow on A-AFW Pump," December 4, 2001

Technical Manual M-021000061, "Instruction Manual for Ingersoll Rand Centrifugal Pumps," Revision 25

UOTE 92-048, "Callaway Response to NRC Generic Letter 91-82," February 10, 1992

Watson Tomlinson, "Evaluation of Auxiliary Feedwater Pump 1A Event 12/3/01," January 21, 2002

Modification Documents

Request For Resolution 21798, Revision D, "Evaluate Permanent Removal of TAP01 Floating Cover," February 1, 2002

Request For Resolution 04991, "Permanent N2 for the Condensate Storage Tank," Revision A, May 4, 1988

Restricted Modification Package 88-2016, Revision A, November 20, 1992

Procedures

Procedure APA-ZZ-00500, "Corrective Action Program," Revision 31

Procedure OSP-AL-P001A, “Motor Driven Aux. Feedwater Pump ‘A’ In Service Test,” Revision 27

Procedure OSP-AL-00001, “AFW Flow Paths Valve Alignment,” Revision 5

Procedure OSP-AL-V001A, “Train ‘A’ Auxiliary Feedwater Valve Operability,” Revision 25

Procedure OSP AL-00002, “AFW to Steam Generators Flow Path Verification,” Revision 3

Procedure OSP-AL-V0002, “Auxiliary Feedwater Valve Operability Test,” Revision 12

Procedure OSP-AL-V0003, “Auxiliary Feedwater Pump Discharge Check Valve Closure Test,” Revision 2

Procedure QPC-ZZ-05046, “Ultrasonic Examination Procedure for Determining Liquid Level in Pipes and Components,” Revision 0

Procedure OSP-ZZ-00001, “Technical Specification Logs,” Revision 37, December 2-5, 2001

Procedure OTG-ZZ-00004, “Power Operation,” Revision 35

Procedure OTN-AE-00001, “Feedwater System Operation,” Revision 23

Procedure OTN-AL-00001, “Auxiliary Feedwater System Operation,” Revision 7

LIST OF ACRONYMS USED

AIT	Augmented Inspection Team
AFW	Auxiliary Feedwater
CARS	Callaway Action Request System
CATS	Callaway Action Tracking System
CCDP	Conditional Core Damage Probability
CDF	Core Damage Frequency
CFR	Code of Federal Regulations
CST	Condensate Storage Tank
IN	Information Notice
LOOP	Loss of Offsite Power
NPSH	Net Positive Suction Head
PRA	Probabilistic Risk Assessment
PSA	Probabilistic Safety Assessment
QA	Quality Assurance
SDP	Significance Determination Process
SIT	Special Inspection Team

ATTACHMENT 2

AUGMENTED INSPECTION TEAM CHARTER

UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION IV
611 RYAN PLAZA DRIVE, SUITE 400
ARLINGTON, TEXAS 76011-8064

January 31, 2002

MEMORANDUM TO: Troy Pruett
Senior Reactor Analyst

FROM: Ellis W. Merschoff
Regional Administrator /**RA**/ BY TPGwynn

SUBJECT: CHARTER FOR THE AUGMENTED INSPECTION TEAM AT THE CALLAWAY PLANT

In response to recently developed information stemming from the continuing evaluation of the impact of the Train A motor-driven auxiliary feedwater (AFW) pump failing to deliver required flow to the steam generators during a controlled reactor plant shutdown performed on December 3, 2001, the ongoing special inspection at the Callaway Plant is being upgraded to an augmented inspection team (AIT). You are hereby designated as the AIT leader.

A. Basis

On December 3, 2001, the licensee manually started the motor-driven AFW pumps prior to breaking condenser vacuum in anticipation of losing the operating main feedwater pump during a controlled plant shutdown. After the main feedwater pump tripped on low vacuum, as expected, the operators noticed the Train A motor-driven AFW pump was not delivering the required flow to the steam generators. The licensee manually stopped the A Train AFW pump and started the turbine-driven AFW pump to provide necessary cooling flow to the steam generators. The initial risk assessment for this condition indicated an estimated conditional core damage probability (CCDP) of 1.1E-6. As a result of this risk assessment, a Special Inspection Team was initiated in accordance with NRC Management Directive 8.3, "NRC Incident Investigation Program." The special inspection started onsite inspection activities at the Callaway Plant on January 28, 2002.

On January 27, 2002, the licensee's investigation revealed that polyurethane foam from a degraded condensate storage tank (CST) floating diaphragm may have caused the pump failure. The revised risk assessment, which takes into account the potential common cause impact on the AFW pumps, indicates a preliminary estimated CCDP in the range of about 5E-5 to 5E-4. Management Directive 8.3 requires the consideration of the initiation of an AIT when the estimated CCDP is greater than or equal to 1E-5. On the basis of a potential for a substantial increase in risk stemming from common mode failure implications, the ongoing special inspection is being upgraded to an AIT, consistent with the guidance in Management Directive 8.3.

An AIT will be dispatched to better understand the cause of the AFW pump failure, the extent of impact on the remaining AFW pumps, and operator actions leading up to and including the event. The team is also tasked with gaining a better understanding of the licensee's common mode failure analysis as related to their root cause(s). The team should build on the work already accomplished by the Special Inspection Team.

B. Scope

Specifically, the team is expected to perform data gathering and fact-finding in order to address the following:

1. Develop a complete description and sequence of events related to the subject AFW pump failure (including the degraded CST floating diaphragm), and operator actions taken in response to regain feedwater flow.

2. Review the licensee's root and probable cause determination for independence, completeness, and accuracy, including the licensee's assessment of the risk associated with the condition.

3. Assess the timeliness and effectiveness of the licensee's evaluation of potential AFW pump common cause failure stemming from the degraded condensate storage tank floating diaphragm.

4. Determine to what extent the degraded CST floating diaphragm could potentially impact plant equipment. In addition to the AFW system, this review should assess the potential impact on any other components and systems, which may be affected.

5. Identify any human factor, procedural or quality assurance deficiencies that may have contributed to the condition.

6. Identify and assess the licensee's evaluation of applicable industry operating experience.

7. Identify and assess the licensee's prompt and long-term corrective actions to address the root and probable causes of the condition.

8. Review the overall adequacy of the licensee's response to the failure of the AFW pump.

C. Guidance

This memorandum designates you as the AIT leader. Your duties will be as described in Inspection Procedure 93800, "Augmented Inspection Team." The team composition has been discussed with you directly. During performance of the augmented inspection, designated team members are separated from their normal duties and report directly to you. The team is to emphasize fact-finding in its review of the circumstances surrounding the event, and it is not the responsibility of the team to examine the regulatory process. Safety concerns identified that are not directly related to the event should be reported to the Region IV office for appropriate action.

The team will report to the site, conduct an entrance meeting, and begin inspection on Thursday, January 31, 2002. Tentatively, the inspection should be completed by close of business February 2, 2002, with a report documenting the results of the inspection, including findings and conclusions, issued within 30 days of the public exit meeting. While the team is on site, you will provide daily status briefings to Region IV management.

This Charter may be modified should the team develop significant new information that warrants review. Should you have any questions concerning this Charter, contact Art Howell III, Director, Division of Reactor Safety at (817) 860-8180.

ATTACHMENT 3

SEQUENCE OF EVENTS

Date and Time	Event
July 1982	Plant personnel performed the final CST closeout inspection.
June 20, 1983	Startup Field Report AP-004A initiated to address oxygen specifications for water from the CST.
July 11, 1983	SWR AP015 installed flanged connections to the CST lower manway and added a suction and discharge line inside the tank. The discharge line extended across the tank. CST drawings were not updated.
January 2, 1985	Temporary Modification 85-M-001 documented CST manway connections, but the internal tank piping configuration was not updated.
June 6, 1985	Drawing M-22AP01 was revised to show manway connections; however, internal tank pipe configuration was not recognized.
September 16, 1991	A modification is requested to sparge nitrogen. The impact of sparging nitrogen into the CST was not evaluated.
December 18, 1991	NRC issues Information Notice 91-82, "Problems With Diaphragms in Safety-Related Tanks."
January 21, 1992	Corrective Action Tracking System CATS 31040 was generated to develop a periodic inspection activity of the CST.
February 10, 1992	The licensee issued a response to Information Notice 91-82 (UOTE 92-048) stating that action was initiated to inspect the tank internals for degradation.
February 1, 1999	Particulate matter was found in CST sampling equipment. Work Order 197670 was initiated to clean and inspect the inside of the CST during Refueling Outage 10.
September 15, 1999	Upon questioning by the NRC resident inspector, the licensee reviewed its records and determined CATS 31040 was closed without the task being accomplished. CARS 199901955 was initiated.
September 16, 1999	Generic Work Request G631231125 was initiated to inspect the CST floating diaphragm.

Date and Time	Event
December 1, 1999	Work Order W201820 replaces Generic Work Request G631231125. CST floating diaphragm inspection was planned for the Spring of 2000.
January 27, 2000	Work Order W202393 supercedes Work Order W197670.
October 17, 2000	The licensee performed an limited scope visual inspection of the CST floating diaphragm and found no degradation.
November 14, 2000	The licensee established a preventive maintenance program to inspect the CST floating diaphragm every 10 years.
March 31, 2001	Work Order W202393 is deferred from Refueling Outage 10.
December 3, 2001 at 1:15 p.m.	Operations personnel commenced a reactor shutdown to Mode 3 in order to repair a leaking main generator bushing.
December 3, 2001 at 10:39 p.m.	Operations personnel received high vibration alarms on main turbine Bearing Number 4. Vibration levels are recorded as 8.72 mils and increasing.
December 3, 2001 at 10:48 p.m.	Operations personnel manually trip the main turbine in response to high vibration.
December 3, 2001 at 10:56 p.m.	Operations personnel manually started AFW Pump B in anticipation of breaking main condenser vacuum.
December 3, 2001 at 10:56 p.m.	Operations personnel manually started AFW Pump A.
December 3, 2001 at 10:57 p.m.	Operations personnel broke main condenser vacuum in response to main turbine bearing vibration levels exceeding 15 mils.
December 3, 2001 at 10:58 p.m.	AFW Pump A ceased to provide flow to Steam Generators B and C. Operations personnel started the turbine-driven AFW pump and dispatched the field supervisor and an equipment operator to AFW Pump Room A.
December 3, 2001 at 11:01 p.m.	The field supervisor and an equipment operator observed no leak-off flow from the outboard packing gland on AFW Pump A. The field supervisor left AFW Pump Room A and inspected the turbine-driven AFW pump.

Date and Time	Event
December 3, 2001 at 11:05 p.m.	The field supervisor returned to AFW Pump Room A. The outboard packing gland was hot to the touch.
December 3, 2001 at 11:07 p.m.	The field supervisor recommended that AFW Pump A be secured. Control room personnel secured AFW Pump A.
December 3, 2001 at 11:19 p.m.	The reactor entered Mode 3.
December 3, 2001 at 11:47 p.m.	Operations personnel vented AFW Pump A and observed 15 seconds of air (not steam).
December 4, 2001 at 1:30 a.m.	The licensee convened an event review team to investigate AFW Pump A failure.
December 4, 2001	The licensee initiated CARS 200107423, assigned a root-cause analyst to the event, and classified the event as Significance Level 1.
December 4, 2001	The licensee verified proper system alignment for AFW Pump A.
December 4, 2001	The licensee evaluated Significant Operating Experience Report 97-01 for potential gas binding of AFW Pump A.
December 4, 2001	The licensee reviewed past operating and maintenance activities for AFW Pump A.
December 4, 2001	AFW Pump A was started with operations and engineering personnel present. Normal packing leak-off was observed, but the outboard packing gland reached a temperature of 190°F after 4 minutes of operation. The pump was secured, the outboard packing was replaced, and the licensee re-baselined the inservice testing performance criteria.
December 5, 2001	AFW Pump A was declared operable. The formal root cause team was developed with personnel from system engineering and the corrective action group.
December 6, 2001	The licensee formally initiated the root cause investigation for the failure of AFW Pump A.

Date and Time	Event
December 14, 2001	The licensee held a teleconference with the pump vendor to discuss the pump malfunction. The vendor suggested that an inspection of the seal water cooling line to the inboard and outboard packing housing be completed.
January 8, 2002	The licensee conducted a meeting to discuss AFW performance issues. A member from regulatory affairs, engineering, and two contractors were added to the root cause team.
January 9, 2002	The licensee narrowed the cause of the event to three possibilities: (1) low NPSH (2) nitrogen gas disassociation, and (3) foreign material. Foreign material was not considered a credible failure mechanism.
January 11, 2002	The licensee completed ultrasonic testing of the AFW suction lines. No significant air or gas accumulation was identified.
January 15, 2002	The licensee performed a surveillance test of AFW Pump A while the Dominion Engineering and Flowserve representatives were on site. The licensee found foam material in the orifice of the AFW Pump A seal water cooling line.
January 17, 2002	The licensee initiated daily ultrasonic testing of the AFW suction lines.
January 23, 2002	The licensee concluded that inadequate NPSH and nitrogen disassociation were not the causes of air-binding in AFW Pump A.
January 24, 2002	The licensee initiated an inspection of the CST floating diaphragm. The team size associated with the root cause was expanded to accommodate the CST inspection.
January 26, 2002	The licensee retrieved approximately 14 inches of foam from the diaphragm seal from the CST sump. The diver also removed approximately 25 inches of foam that was hanging from a 6 foot damaged section of the diaphragm seal. Approximately 20.5 inches of foam from the 71 inch damaged section was missing.
January 28, 2002	The NRC special inspection team arrived on site.
January 30, 2002	The licensee inspected the small bore piping, first and last stage impellers, and part of the suction piping for AFW Pump B.

Date and Time	Event
January 31, 2002	The licensee performed a reactor shutdown to Mode 4 to inspect the AFW system. The NRC upgraded to an augmented inspection team (AIT). The licensee increased the scope of the root cause investigation.
February 1, 2002	The licensee began draining the CST. The licensee initiated foreign material inspections for the AFW system.
February 2, 2002	The licensee inspected the CST floating diaphragm. The licensee commenced removal of the CST floating diaphragm and replacement of the rotating assembly on AFW Pump A.
February 5, 2002	Inspections on the AFW system were completed.
February 6, 2002	The CST is restored. AIT completes onsite inspection activity.

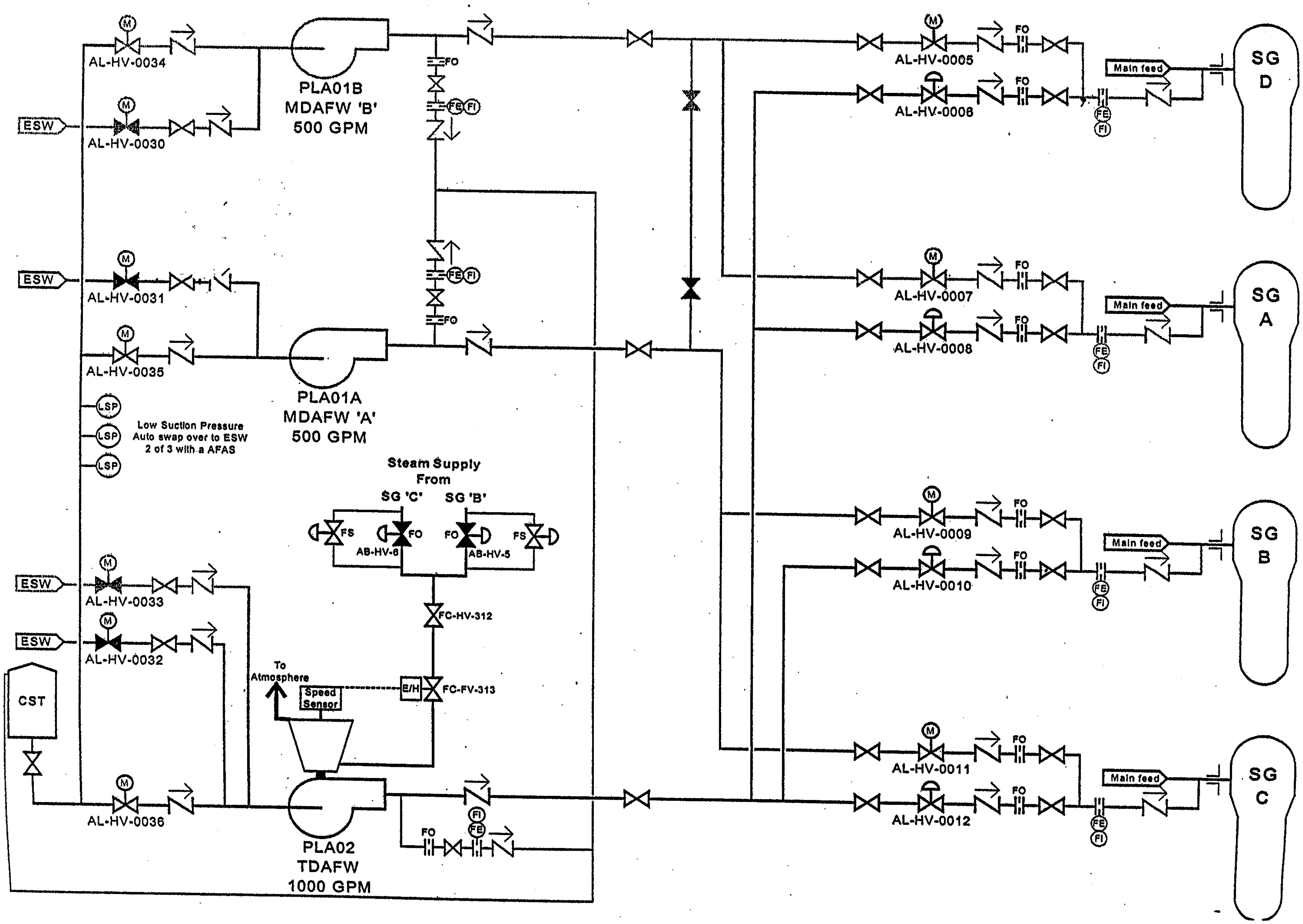
ATTACHMENT 4

SYSTEM FIGURES

Figure 1

Auxiliary Feedwater System

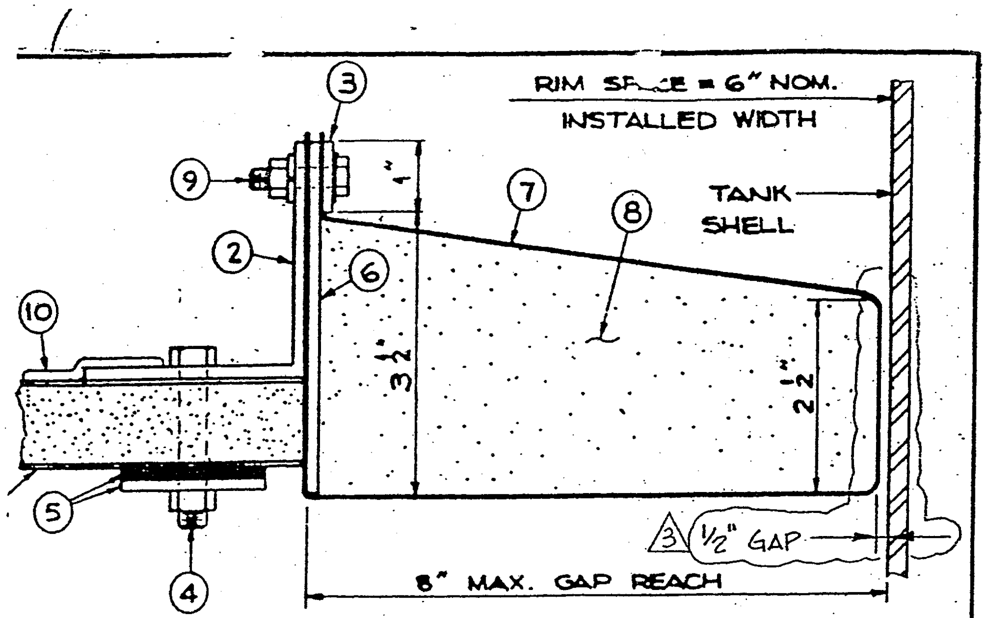
Simplified Diagram



ESW
ESW
ESW
ESW
AL-HV-0034
AL-HV-0030
AL-HV-0031
AL-HV-0035
AL-HV-0033
AL-HV-0032
AL-HV-0036
CST
LSP
LSP
LSP
Low Suction Pressure
Auto swap over to ESW
2 of 3 with a AFAS
PLA01B
MDAFW 'B'
500 GPM
PLA01A
MDAFW 'A'
500 GPM
PLA02
TDAFW
1000 GPM
Steam Supply
From
SG 'C'
SG 'B'
FS
FO
AB-HV-6
AB-HV-5
FC-HV-312
FC-FV-313
E/H
To
Atmosphere
Speed
Sensor
FO
FE
FI
M
AL-HV-0005
AL-HV-0006
AL-HV-0007
AL-HV-0008
AL-HV-0009
AL-HV-0010
AL-HV-0011
AL-HV-0012
Main feed
SG
D
SG
A
SG
B
SG
C

Figure 2

Condensate Storage Tank
Diaphragm Seal



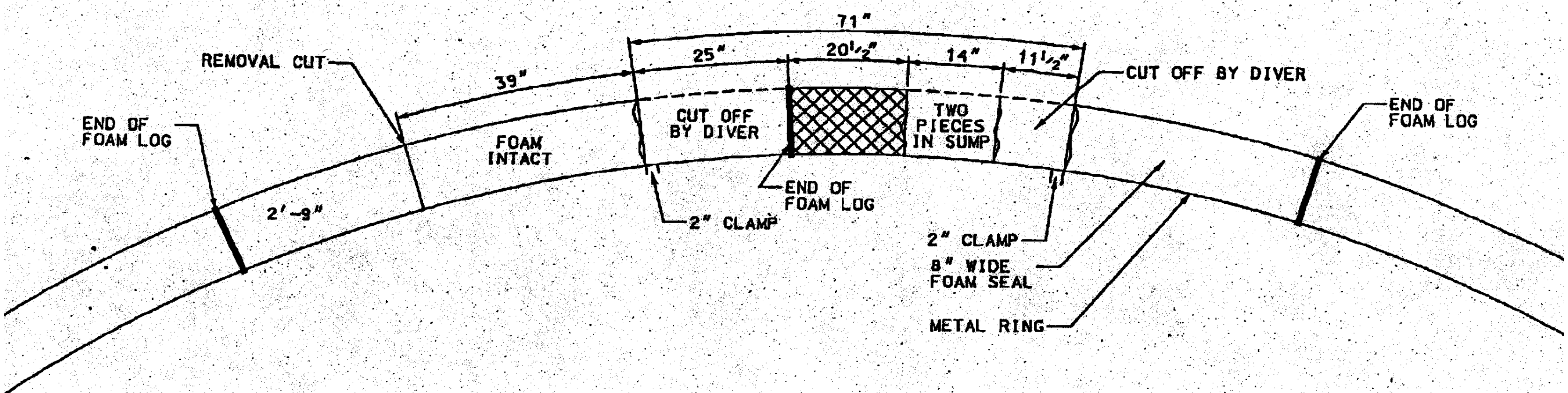
1. FIBERGLASS PANEL
2. 3 × 3 × 3/16 FRP ANGLE
3. 1 × 1/8 ALUM. BAR 6063-T52
4. 3/8"ø NYLON BOLT × 2" LG. W/NYLON NUT
5. 2" ø (#R-437-H BUNA-N) & NYLON WASHERS (NON-METALLIC)
6. 1/8" × 4 1/2" HIGH FOAM POSITIONER (MASONITE)
7. TEFLON COATED FIBERGLASS FABRIC
8. FOAM (3 1/2" & 2 1/2" HIGH) × 8" WIDE (FLEXIBLE POLYURETHANE)
9. 1/4"ø (2024-T4 ALUM.) BOLT X 1" W/(6061-T6 ALUM.) NUT & LOCK WASHER
10. FIBERGLASS & POLYESTER RESIN HAND LAYUP
11. FOAM BONDED TO MASONITE W/CHEMLOCK 7000 URETHANE ADHESIVE

Figure 3

Degraded Diaphragm Seal

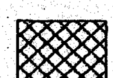
DAMAGE TO CST SEAL

NOT TO SCALE



NOTES:

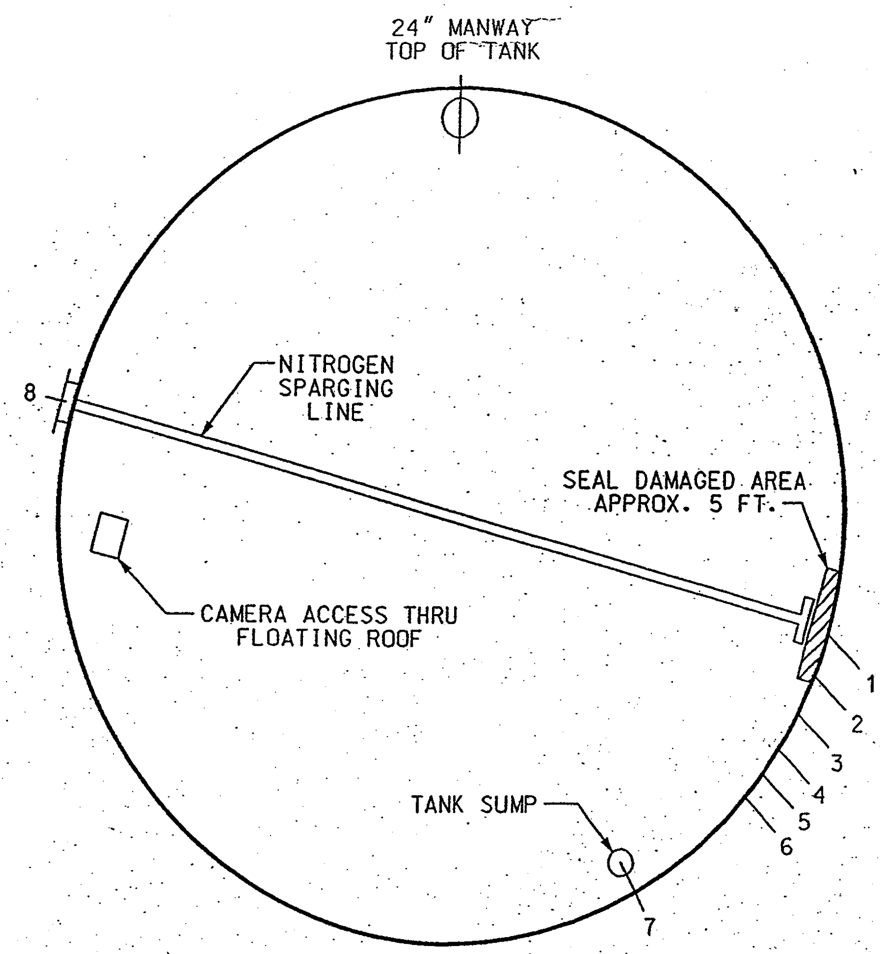
1. RADIUS OF METAL RING IS 21'-0".
2. DIMENSIONS ARE TAKEN ALONG METAL RING.



MISSING FOAM

Figure 4

Condensate Storage Tank Configuration



Line No.	Elevation
1. 8" Tank Overflow	42 Ft.
2. 12" Aux Feedwater Supply	1 Ft.
3. 3" Aux Feedwater Mini-flow	3.5 Ft.
4. 10" Condenser Make-up	20.5 Ft.
5. 6" Hotwell Reject	3.5 Ft.
6. 4" Make-up Inlet	3.5 Ft.
7. 8" Drain to Condenser	-3.5 Ft.

8. 24" Manway with pipe connections for De Oxy Trailer & N_2 Sparge